Improving Pedestrian Operations at Innovative Geometric Designs

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ABSTRACT

Innovative geometric designs have shown an ability to significantly improve operations for vehicles in the proper context. Improvements can still be made on improving the operations for pedestrians at various innovative designs. Improving the pedestrian aspects can lead to these designs being implemented in more contexts and incorporating them into complete street projects. This paper investigates various traffic operations and geometric design elements to improve pedestrian operations specifically at superstreets and diverging diamond interchanges. The elements include new crosswalk locations, geometric changes, coordinated pedestrian signal timing, various phase combinations, and other elements seen at more conventional designs.

INTRODUCTION

Innovative geometric designs (IGDs) such as diverging diamond interchanges (DDI), superstreets (SS), continuous flow intersections (CFI), median u-turn intersections (MUT), continuous-T intersections (C-T), quadrant roadway (QR), and jughandles (JUG) have proven to improve traffic operations and reduce crashes for a significantly lower cost than more traditional intersection designs in many applications.

For many years, the focus on IGDs has been to maximize performance for vehicular traffic with less focus on non-vehicular movements such as pedestrians and cyclist. This was somewhat necessary because if these designs did not work for vehicular traffic, there would be no need to worry about other design elements. Now that innovative designs have proven themselves for vehicular traffic, there needs to be a greater focus on how to best design for other users.

This paper focuses on the pedestrian issues related to innovative geometric designs with the aim to improve the design for pedestrians in these designs with geometric and/or traffic operational improvements.

LITERATURE REVIEW

The Federal Highway Administration (FHWA) published four informational guidebooks in 2014 (1-4) for DDIs, restricted crossing u-turns (RCUT, also known as superstreets and j-turns), MUTs, and displaced left turn intersections (more commonly known as continuous flow intersections). Each guidebook has a chapter focusing on pedestrian and bicycle issues.

These pedestrian/bicycle chapters attempted to primarily focus on "best practices" as well any research on the topic.

Unfortunately, the "best practices" were based on designs where the primary focus was overwhelmingly for the vehicular traffic and the pedestrian/bicycle accommodations were more like a best fit under the circumstances that prioritized vehicular movement. This best-fit accommodation was due to both a lack of guidance regarding designing for pedestrians and cyclists as well as being built in contexts where pedestrian and bicycle traffic was usually very low.

Therefore the FHWA guidebook needed to extend beyond just best practices and research specifically related to pedestrians at IGDs. So the guidebooks try to also incorporate best practices at conventional intersections into the IGD designs. While, these elements in the FHWA guidebooks definitely improve pedestrian designs from the current "best practices", there is still plenty room for more improvement.

In 2014, TRB held an Alternative Intersections and Interchanges Symposium in Salt Lake City, Utah. There were several presentations on pedestrian accommodation at IGDs at the symposium, which can be viewed here: http://teachamerica.com/ai14/. From the symposium, a major research need that was discussed was to develop a guide for better pedestrian and bicycle accommodations at IGDs. However, there has been very little research on this topic since the symposium.

Fortunately, in April 2017, NCHRP Project 07-25 began on this specific topic, with a projected completion in early 2019.

APPROACH

This paper is a qualitative look into possible improvements of pedestrian accommodations to various IGDs. This is based on observations actually walking many existing IGDs across the US as well as design experience with these IGDs.

It needs to be noted that there will be many potential improvements proposed in this paper. Not every improvement is necessarily based on every circumstance. The design needs to be based on the context of the location of the intersection. Contexts with high pedestrian volume could be quite different than contexts with low pedestrian volume. It is also possible that the design could be influenced if the pedestrian peak volumes are significantly different than the vehicular peak volumes.

General Principles to Consider

Pedestrian Sight Distance (PSD)

This is a problem at all intersection types whether it is conventional or an IGD. The problem occurs when the crosswalk is located in a place where a pedestrian cannot clearly see the approaching vehicle and/or the driver cannot see the pedestrian at least at the beginning of the crossing.

From an IGD point of view, this PSD is most common at uncontrolled crossings at DDIs. Examples include crossings at right exits such as the crossing over the westbound (WB) to northbound (NB) movement at I-580 / Moana Lane in Reno, Nevada and left exits such as the eastbound (EB) to NB movement at I-15 / Pioneers Crossing in American Fork, UT (DDI over interstate) and the WB to southbound (SB) movement at US 65 / Chestnut Expy in Springfield, MO (DDI under freeway).

This can also be a problem at crossings at uncontrolled crossing at JUG ramps for very similar reasons to DDI crossings at right exits.

Parallel vs Perpendicular Crossings

Most guidance given for pedestrian crossings suggests providing a perpendicular crossing. The main theory behind this is that the pedestrian has the least exposure to the roadway. In many cases, particularly at uncontrolled crossings, a perpendicular crossing would be considered the safest crossing, but not always.

If a perpendicular crossing causes a PSD issue, then a parallel crossing or hybrid (somewhere between a parallel and perpendicular) crossing would be safer. A good example of this is the pedestrian crossing over the left exits at the I-590 / Winton Road DDI in Brighton, NY. Notice that the pedestrian crossings are parallel to the roadway instead of perpendicular to the ramp. This allows the pedestrian to see oncoming vehicles (even though it is not the ideal angle from certain locations) and drivers can definitely see the pedestrians while approaching the ramp from under the interstate bridges.

A parallel crossing also provides a little more spacing between the crosswalk and the stop bar when applicable at signalized intersections. This extra spacing may provide a buffer that increases the margin of error of a vehicle entering a crosswalk if the driver overshoots the stop bar.

There is also an operational advantage to parallel crossings for a pedestrian. Parallel crossings provide the most direct route for pedestrians the vast majority of the time. Often this operational advantage for pedestrians has little to no operational disadvantage for vehicular traffic at signalized crossings as long as the concurrent green phase for vehicular traffic requires more green time for the pedestrian crossing.

The only other disadvantage possible for vehicular traffic at parallel crossings with concurrent phasing is for turning traffic into the crosswalk. This disadvantage would increase if there is a platoon of pedestrians crossing during a similar phase. The reason for this is that pedestrians would be blocking the intersection longer for vehicles attempting to make a turn.

There is a potential advantage for vehicular traffic with parallel crossings at signalized intersections. Parallel crossings may provide an opportunity to move the stop bar closer to the intersection which would decrease the clearance time needed during phase transitions and get an extra vehicle or two through the intersection at the beginning of a phase.

There is another potential advantage for pedestrians to parallel crossings which is increased accessibility. This can be true for visually impaired pedestrians, where direct crossings decrease confusion. This can also be true for pedestrians with wheelchairs or strollers where turns that are needed near the crosswalk for perpendicular crossings can be more difficult, particularly if there is limited space. The I-15 / Pioneer Crossing DDI crossing referenced earlier is a great example of this difficulty.

Lastly, perpendicular crossings are not always followed by pedestrians anyway. In general, pedestrians will cross at the location of least resistance. If a pedestrian does not see an inherent advantage of using a perpendicular crossing at a crosswalk compared to a shorter unmarked parallel crossing, many times the pedestrian will take the shorter crossing.

For all of these reasons, parallel crossings should be given greater considerations particularly at signalized intersections. If a signalized intersection does not have conflicting turning movements with concurrent vehicular/pedestrian phases, such as at DDI crossovers, and the required time for a parallel pedestrian crossing is shorter than the concurrent vehicular green phase, it almost always makes sense to choose a parallel crossing over a perpendicular crossing. Parallel or hybrid crossings can often make sense at uncontrolled crossings if there is a PSD issue with a perpendicular crossing.

Exclusive Pedestrian Phase

One of the main reasons why IGDs are so efficient operationally for vehicular traffic is due to the reduction of signal phases within a cycle. In many cases, IGDs only have two concurrent phases within a cycle. For this reason, exclusive pedestrian phases at IGDs may not cause the intersection to reach capacity for vehicular traffic, particularly in the non-peak hours.

For instance, suppose pedestrian volumes increase significantly during non-vehicular peak periods. This might occur near trails that are used for recreational purposes on the weekends and holidays or perhaps during school hours, which avoid the PM peak. Exclusive pedestrian phasing could be a strategy that gives higher priority to pedestrians when needed most, while being rarely utilized if at all during times when vehicular traffic would suffer most.

Lead or Lag Pedestrian Phase

When a full exclusive phase would adversely affect vehicular traffic too much, another potential option would be to provide a lead pedestrian phase, where the pedestrian walk phase would begin several seconds before the concurrent vehicular phase. This can be an advantage to pedestrians when then there are turning movements that enter a crosswalk during a concurrent vehicular/pedestrian phase. The use of a lead pedestrian phase can be useful in certain IGDs as will be explained later in the paper.

A pedestrian lag phase could also be useful in situations where pedestrians may be expected to arrive near the end of a phase.

CLOSER LOOK AT INDIVIDUAL IGDs

With some of these general principles in mind, this paper will now focus on individual IGDs.

Diverging Diamond Interchanges

Parallel vs Perpendicular Crosswalks

Parallel Crosswalks would seem to be preferred in many circumstances at the crossover intersections since there will be no turns into the crosswalks with concurrent phasing and the pedestrian crossing time will rarely need more time than the concurrent vehicular phase. Pedestrians will have a more direct route and better accessibility in general with no additional safety or operational issues for any user.

Crosswalks over ramps may depend on the context of each ramp to determine whether a crosswalk should be parallel, perpendicular, or a hybrid of the two. Some items to consider:

Is there a PSD issue? If so, can it be eliminated? Some obstacles that create PSD issues can more easily be removed than others, such as landscaping or a fence. Others are nearly impossible to remove, such as bridge abutments and piers. If a perpendicular crossing will have unavoidable PSD issues, a parallel or hybrid crossing should very likely be designed that mitigates the PSD issue.

Is the vehicular volume high along the ramp? If so, a perpendicular crossing would be preferred. If the crossing is uncontrolled, the pedestrian will want the shortest exposure to traffic. In the more likely event that the crossing is signalized, the pedestrian crossing will be a conflicting phase with vehicular traffic and will want to be as short as possible.

How fast is the design speed at the crosswalk? If the geometry of the ramp encourages high speeds, shorter crossings with likely a perpendicular crossing is more advisable to limit exposure and to allow the pedestrian to better judge gaps by looking to the side instead of behind the shoulder. If the geometry slows down vehicular speeds, a parallel or hybrid crossing may become more preferable depending on other aspects of the ramp. Slower vehicular speeds at the crosswalk are better for the pedestrian from both a safety and operational perspective and should be encouraged at most crosswalks. However, there will be conditions where the operations and possibly safety concerns of the DDI (such as significant speed changes from a choice lane to a ramp) may require higher speeds for certain ramp movements.

Location of sidewalks between crossings

The most ideal location for sidewalks within a DDI is sidewalks that are most direct from getting from one side of the interchange to the other. There are two main reasons for this. Operationally, this is the most efficient path for a pedestrian and minimizes geometric delay for pedestrians. It also discourages pedestrians from walking along the outside of a DDI when the sidewalk is in the median between crossovers. This behavior has been observed at several DDIs and is not safe.

Pedestrian Phase Coordination between crossings

At DDIs with signal control at all crossings, there are opportunities to provide better progression for the pedestrian between crossings particularly when one of the crossings is across the right exit to the on-ramp.

In most cases, the signal phase for the right exit on-ramp that is signalized can be independent from all the other phase at the crossover. This is because both the right exit and left exit to the on-ramp generally each have their own lane or lanes initially and each flow of traffic merges together downstream along the ramp or after entering the highway. Therefore, in the case of a DDI with a median sidewalk between crossovers, it should be possible in many cases to time the pedestrian phases to or from the crossover crosswalk and the right-exit on-ramp crosswalk. There is even more flexibility possible in coordinating the pedestrian crossings when the sidewalk is on the outside of the DDI if the left exit to the on-ramp can also be independent from the other crossover signal phases.

The geometry can play a role in the coordination of pedestrian phases for the off-ramp crossings. In DDIs with median sidewalks, the pedestrian phase for the crossover needs to be the same phase as the crosswalk over the right exit off-ramp. The longer the stretch of sidewalk is between these two crossings, the more likely the pedestrian will need to stop at the second crossing. Therefore, the geometry of the right-turn off-ramp should ideally be as close as possible to the crossover for the pedestrian.

When the sidewalk in the DDI is on the outside, there is a different logic. There will never be a period in most DDIs where the left-turn off ramp and right-turn off-ramp are both red (besides very small transition periods between phases), allowing pedestrian crossings over both ramps in the same phase. Therefore, the longer the sidewalk is between the left-turn off-ramp crossing and the right-turn off-ramp crossing, the less delay a pedestrian is likely to experience while improving the chance that the pedestrian will get consecutive walk phases. This distance between the crossings should be one of several considerations when determining the placement of the ramp termini and may need to be balanced with other operational and safety issues for both the pedestrian and the driving public.

Superstreet

Placement of Crossings

Nearly all SSs follow the "Z" crossings which is also the recommendation in the FHWA guidebook on RCUTs. The logic of this placement is pretty simple. When crossing the major road in the Z crossing, there are no concurrent phases that turn into the crosswalk. This is a major safety advantage to pedestrians and an operational advantage to vehicular traffic.

But it is not an operational advantage for the pedestrian. If a pedestrian wants to just go straight across the major road, say the SE corner to the NE corner, it requires a three-stage process. First, the pedestrian must cross the side road from the SE corner to the SW corner. Then in a different pedestrian phase, the pedestrian needs to cross from the SW corner to the median. Lastly, the pedestrian needs to cross from the median to the NE corner at a signal that could possibly have no coordination with the previous crossing.

Now consider pedestrian crossings in Figure 1, by introducing Points G and F. Although crossing from point D to point B is still a three-stage crossing, the first crossing is nearly guaranteed a walk phase upon arrival unless the phases are in transition. This is because the pedestrian could cross to either point C or G immediately depending on which crossing has the walk phase and then wait for the next phase to cross to point B.

The initial disadvantage of this new crossing is that the D-G crossing would have a concurrent phase with the NB right turn movement creating a conflict of turning vehicles with pedestrians. This can be avoided completely in some cases by having a separate G-D pedestrian phase. In this example, the crossing is only over two lanes, so the pedestrian phase can be relatively short.

In other cases, the G-D crossing can have a pedestrian lead or lag phase depending on which side initiates the crossing. If crossing from G to D, a pedestrian lead phase would be beneficial, since the pedestrian will be crossing from E to G which will be followed by the G to D phase. If crossing from D to G, a pedestrian lag phase would be beneficial, because the next phase will be D to G and a lag phase would minimize the wait to the next phase.

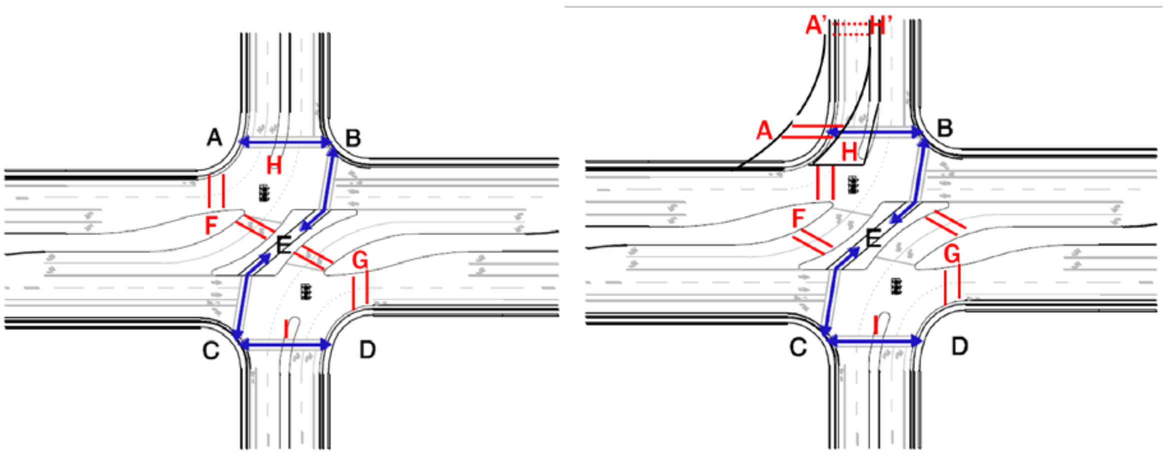

FIGURE 1A and 1B Superstreet Crossing Options (1)

Another possible crossing opportunity could be from points F to H with a small geometric improvement as shown in Figure 1B. This crossing would then eliminate the potentially conflict of concurrent pedestrian phase with right turning traffic, when compared to crossing from points F to A. Another possible advantage for right turning traffic is being guided directly to the u-turn lanes.

The downside to this option is that it does require a fourth crossing. The fourth crossing could be from H to A, which will likely be another phase change or a crossing from H' to A'. A sidewalk from H to H' would need to be provided in the median with the second option. The crossing from H' to A' may not need to be controlled depending on the context. If the crossing is signalized, it could be placed strategically at a distance that minimizes delay for both vehicular and pedestrian traffic. See the MD 410/MD 355 intersection in Bethesda, MD for a similar sidewalk strategy that is similar to a sidewalk from H to H'.

Placement of Left Turns for the Major Road

The placement of the left turns can have an effect on the pedestrian crossings. If a superstreet has a slight offset for the minor streets as shown in Figure 2, the pedestrian crossing can have a more direct route. If the offsets are too far apart, then the pedestrian will need to walk in a "backwards Z" in the median which could also mean that pedestrian would be walking with his or her back to traffic. This is not recommended. In case where the offset is too far apart, there may need to be additional pedestrian crossings that are more direct.

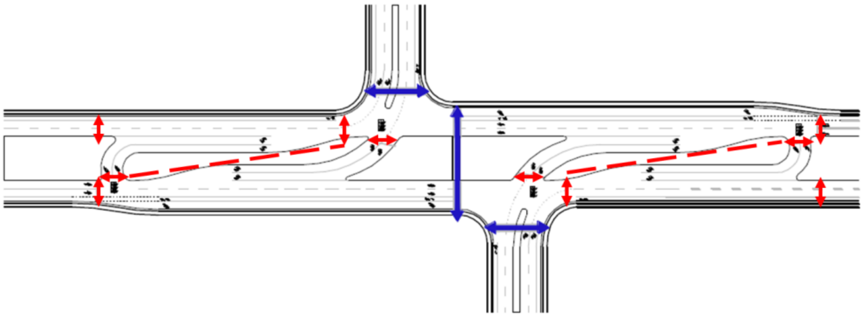

FIGURE 2 Superstreet with Offset Intersections (1)

Another option that would be extremely beneficial to pedestrians is eliminating the direct left turns from the major road to the minor road and forcing those movements to use the u-turn as well. The SS at US 15/501 and Erwin Road in Chapel Hill, NC is an example of this type of SS. If a crossing were provided from the SE corner to the NE corner (as well as SW to NW), the pedestrian crossing over the major road becomes two stages instead of three. It then becomes possible to possibly coordinate the two stages in certain contexts to become just a one stage crossing.

Progression of Pedestrian Crossings

Most traffic signals are designed to maximize efficiency for vehicular movement, which is understandable given that in the vast majority of case, the reason for a traffic signal is primarily for vehicular traffic and secondarily for other movements. But there are ways to reasonably improve pedestrian phases with minimal to no adverse effects for vehicular traffic.

If there are crossings to and from points F or G in Figure 1, a way to improve the pedestrian operations is to separate the left turn and concurrent right turn phases. One possibility would be split-phasing the movements to allow maximum protection for the pedestrian. This case might be easily accommodated during non-peak vehicular peak hours.

It could also mean giving more green time to one movement than the other in concurrent phases. Rarely will the left turn and right turn movements need the same amount of green time in a phase, particularly if turns are allowed on red (flashing yellow left arrow, Right turn on red/RTOR). Instead of having "wasted green time" for one of the movement, this time can be moved to the pedestrian movement to improve pedestrian operations and/or safety.

Another option is to have a pedestrian only phase that allows pedestrians to cross in any direction possible including from points D to E or A to E. Pedestrian-only phases could be limited to just one side of the SS or both sides.

A final consideration is to determine how important it is to coordinate the pedestrian crossings from one side of the major roadway to the other side of the roadway. A major advantage of SSs for vehicular traffic is that theoretically the flow in one direction can be independent from the flow in the other direction. In practice, this is somewhat true in SS corridors, but less true at isolated SS intersections, due to the desire to try to provide progression from the side street to the u-turn signals. Understanding the desired progressions for all movements from both the major road and minor road can help in designing to maximize progression for pedestrians as well.

Placement of Sidewalks

Another possible option to consider for SSs is sidewalks in the median between the main intersection and the u-turn intersections as shown in Figure 2. This provides additional options for the pedestrians to cross to or from the major road and eliminates at least one crossing stage to some destinations.

Sidewalks could also be extended along the median beyond the SS. This could be done in cases where there is either little to no access needed on the outside of the major roadway or there are consistent mid-block crossings and strong "pedestrian access management". Sidewalks in medians could provide a significant safety benefit to pedestrians by avoiding consistent driveway crossings.

Continuous Flow Intersections

Crossing Options at main intersection

There are currently two options provided in the FHWA DLT informational guide regarding pedestrian crossings at the main intersection of a CFI as shown in Figure 3, with options currently in use for each. The first option on the left is a one-stage crossing, but it is a very long crossing and it prohibits the left turn phase to be concurrent with the pedestrian crossing. Both of these issues require long signal phases and cycle lengths.

The second option has shorter crossings that can also be concurrent with the left turn phase, but it requires multiple stages. There is potential to minimize the delay between certain stages, particularly with the crossing the right turn bypass. However, it may be difficult to determine the final destination of pedestrians who initially cross the right turn bypass and displaced left turn ramps.

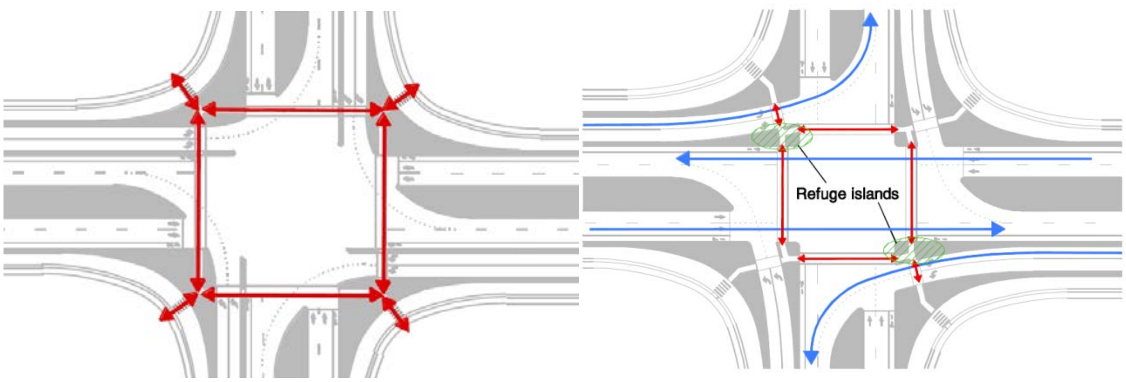

FIGURE 3 CFI Pedestrian Crossing Options in FHWA DLT Information Guide (4)

A third option shown in Figure 4 was proposed by Chlewicki (5), which has gotten a lot of positive reviews from researchers but has been difficult to convince an agency to implement. This option allows for shorter crossings with a concurrent left turn phase like the second option above. But it also allows a one stage crossing at the main intersection that can be coordinated fairly well with the second crossing at the displaced left turn intersection. This option also eliminates any conflicts between pedestrians and turning movements of vehicles in concurrent phases.

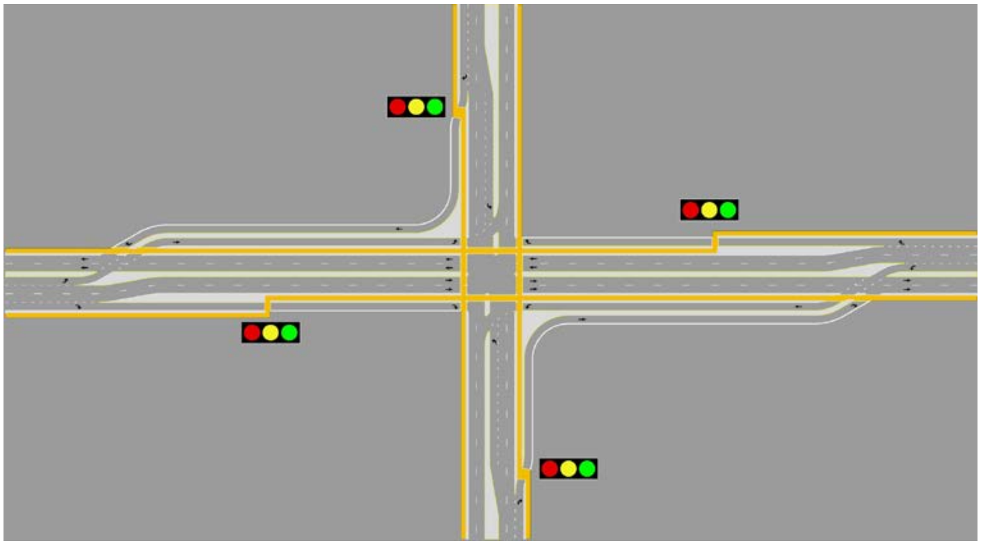

FIGURE 4 New Crossing Locations in CFIs Proposed by Chlewicki (5)

Crossings at DLT intersections

Similar to SSs that provide opportunities for additional “mid-block” crossings at the u-turn intersections, CFIs can provide similar opportunities at the DLT intersections. (Note: DLT in this context refers to the intersection where the displaced left turn begins its maneuver)

The reason why mid-block crossings were likely not considered for earlier CFIs is because the crossing would need at least a three-stage crossing if placed between the DLT and main intersection or an exclusive phase if placed before the left turn.

However, if the sidewalk is placed in between the displaced left movement and opposing thru lane as shown in Figure 4, a crossing inside of the DLT intersection would only need two stages to cross. A mid-block crossing would give pedestrians more options operationally as well as provide more options for mid-block transit stops.

Median Sidewalk Option

A median sidewalk at least between the DLT intersections and main intersection could be a possible option at CFIs and possibly beyond. In many CFI contexts, CFIs are built along access control highways, minimizing the need for sidewalks to access driveways. This option would also shorten the time needed to cross for a pedestrian making a turning movement to the far side of the CFI main intersection. This would allow shorter pedestrian crossing phases when the ped signal is called from the median. Conversely, it would require more time for a pedestrian turning movement to the near side of the CFI.

Reduce Medians at Main Intersections

The FHWA DLT Informational Guide suggests that the geometry on the left side of Figure 5 is preferred over the geometry to the right (4). This is due to preferring tangent sections through the DLT intersection and not because a reduction of the median width is undesirable.

From an operational point of view, a narrower median at the main CFI intersection is preferable to both pedestrians and vehicular traffic since it reduces the clearance time to cross the road. The median width should ideally be at least 6 feet wide to allow for a pedestrian refuge if needed as well better accessibility for visually impaired pedestrians with the spacing of the truncated domes. But there should be careful consideration of making the median width any wider.

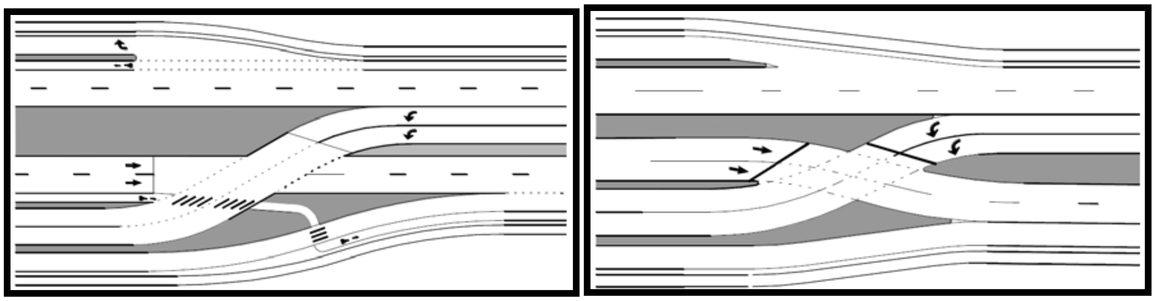

FIGURE 5 Geometry Options of DLT, Left Figure is Preferred over Right Figure (4)

Geometrically, the preferred method of reducing the median width is to introduce a reverse curve for the direction of travel that is not signalized at the DLT intersection.

Signal Timing over Left Turns and Geometric Influence

In nearly all CFIs, the left turn phase for a DLT will need to be a lead phase to maximize the vehicular operations of a CFI. In most cases, the required left turn green time will be less than the required concurrent thru phase green time.

Knowing that these two features are likely in the vast majority of CFIs, it will be possible to turn the left turn phase early, which would allow pedestrians a head start in crossing the DLT portion of the main intersection earlier or allow an earlier finish of a crossing for a pedestrian who did not cross the entire intersection.

If this pedestrian phasing scheme is desired, the crosswalks over the DLT and thru movements may need to be slightly offset so that a pedestrian does not get confused to cross the next segment too early. Ideally, the crosswalk over the thru lanes should be closer to the intersection than the crosswalk over the DLT movement, so that pedestrians are looking slightly towards the opposing traffic than vice versa between crossings.

Another option to consider is to provide more spacing between the DLT terminus and the main intersection. This spacing would split up the crossings to smaller segments, which may have safety benefits for the pedestrian. There could be some operationally disadvantages to both the pedestrian and vehicular traffic depending on the distance of the spacing and how well the signals can be coordinated.

Median U-Turn Intersections

Reduced medians at main intersection

Crossings at MUTs are often longer than necessary because the median remains wide between the u-turn movements. Not only is this an operational disadvantage to pedestrians, who might not be able to complete the crossing in one phase, it can also be an operational disadvantage for vehicular traffic for two reasons. First, it will require longer phases and cycles, which increases delay time. Second, the long crossing time may become the critical phase, which will mean that the opposing phase will be waiting longer because of a pedestrian crossing and not opposing vehicular traffic.

For these reasons, it is advisable to reduce the median width of MUTs at the main intersection. Similarly to the discussion for reducing median widths at CFIs, the median width should ideally be six feet wide, unless the median can be eliminated completely. Reverse curves to reduce widths should not be at the median u-turn intersection and ideally be on the side of the road that does not have the traffic signal at the median u-turn opening (if there is no mid-block crossing).

Separating Right Turns from Concurrent Crossing

At MUTs, there is a significant increase in right turn volume. This is because every right turn movement is also including a left turn movement as well in MUTs that do not allow left turns from any direction. This increased right turn movement can potentially be problematic for pedestrians that are crossing concurrently with vehicles making a right turn into the crosswalk and vice versa.

For this reason, pedestrian lead or lag times may be desirable at certain crossings within an MUT. It may even be possible that an exclusive pedestrian phase be desirable in some cases.

Another option could be to displace the right turn movements prior between the median u-turn opening and the main intersection of an MUT. The concept would be very similar to the displaced right turn shown in Figure 5 for the CFI with the displaced right turn crossing possibly being implemented at the median u-turn opening.

Quadrant Roadway Intersections

Reduced Medians

In many cases, part of the reason a QR intersection is needed is due to land constraints at the main intersection that require narrower cross sections. This naturally reduces the median width at these QRs. This is generally beneficial for pedestrians and should be considered at all QRs.

QR vs CFI

The QR can be very pedestrian friendly because it breaks up various turning movements to multiple locations to decrease conflicts between pedestrians and turning vehicles, creating smaller intersections to cross, and provides opportunities for pedestrian short-cuts. There are potential development opportunities around some QRs as well with additional access opportunities along the connecting QR. This can increase the pedestrian friendliness of the entire QR intersection, by decreasing or eliminating driveways between the QR and main intersection.

A QR may want to be considered in locations where a CFI would be useful but there is an increased emphasis on pedestrians. A QR for some movements, such as the advanced left turn and right turn short-cut are extremely similar to a CFI. The QR may provide a lot friendlier pedestrian environment without losing a lot operationally.

Jughandles

Crossings over JUG ramps

Jughandle corridors can often be filled with commercial properties surrounding the corridor. Yet, pedestrian access is often quite weak in these corridors, which is unfortunate since there are so many pedestrian and transit opportunities within these corridors.

One possible reason why pedestrian accommodations are usually poor within the JUG corridors is due to the issue of crossing high speed JUG ramps.

Similar to pedestrian issues regarding crossing interchange ramps, similar methods can be used to provide pedestrian friendlier crossings at JUGs. They include, lowering the design speed of the JUG ramps approaching the pedestrian crossing, providing partial or full signal control of the crossing, adding warning signs on the approach and at the crosswalk, and providing the proper PSD for both the pedestrian and the driver.

Jughandles with forward ramps also provide opportunities for additional pedestrian access along the JUG ramp. (Reverse ramps at JUGs provide additional opportunities for cyclists, which is beyond the scope of this paper.)

Continuous-T Intersections

Crossing the Major Road Fully

A Continuous-T intersection allows the far side thru movement of a T-intersection to be in free-flow. When the C-T is signalized, it is typically three phases for the other movements which includes a thru phase, a left turn phase into the side road, and a left turn phase out of the side road. See Figure 6 for a typical C-T setup.

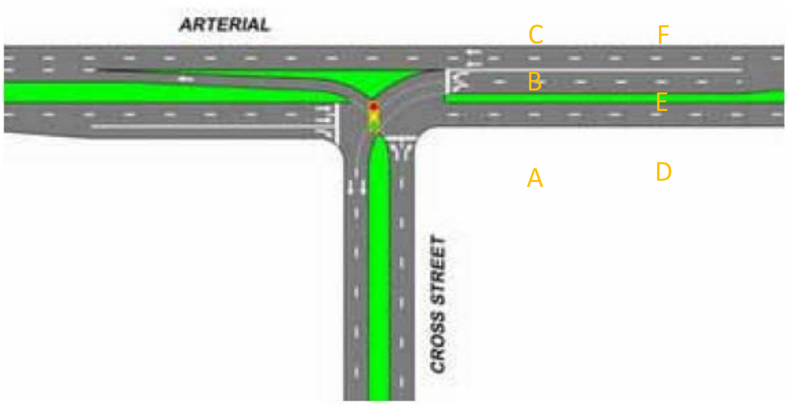

FIGURE 6 Continuous-T Intersection (Figure from attap.umd.edu)

A negative aspect of the C-T design is that it appears that pedestrians cannot safely cross the major road to the free flow nature of the far side. The author knows of several projects, where the C-T made a lot of sense but was eventually killed because of this pedestrian access issue.

However, it is definitely possible to provide safe crossings, if the designer is willing to stop the free flow movement for pedestrian crossings. In Figure 6, the D-F crossing is possible in one stage with a concurrent pedestrian phase with the cross street left turn phase. If desired, there could also be an extension of the pedestrian phase for the D-E crossing during the arterial left turn phase. A pedestrian refuge at point E would likely be desirable with this crossing.

If the crossing is desired on the other side of the intersection, an A-C crossing could be provided with a concurrent phase for the arterial left turn phase. There could also be a desire to have a two-stage crossing from A-B-C and vice versa. A pedestrian refuge area at Point B would likely be desirable at this crossing.

A final alternative is to combine the CFI concept with the C-T concept as can be seen at the MD 210/MD 228 CFI/C-T in Accokeek, MD. Although there are no pedestrian accommodations at this location, this concept would allow a median sidewalk with minor modifications along MD 228 within the CFI and then cross MD 210 between the left turns into and out of SB MD 210.

CONCLUSIONS

This paper qualitatively explored potential techniques to improve pedestrian operations and safety at many types of IGDs. Some techniques may be more universal then others and the context of the IGD location needs to be thoroughly explored to determine what elements might be necessary to improve the pedestrian accommodations at the IGDs.

Designers are encouraged to consider these various design elements and implement them on existing and future IGDs. Pedestrian accommodations will never improve at IGDs if the engineering community does not have the courage to try something new and then learn from observing what happens.

There is plenty of potential for future research from the concepts in this paper as well. Hopefully, a lot of that research will come from NCHRP project 07-25.

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