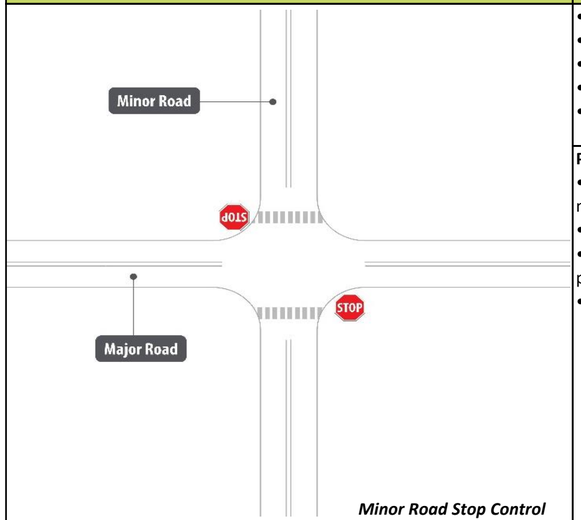
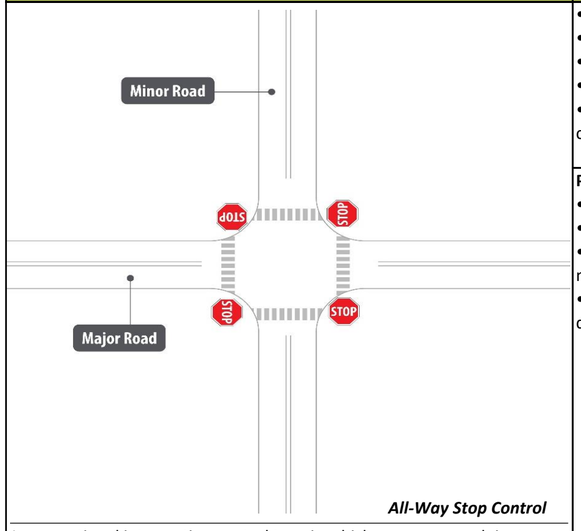
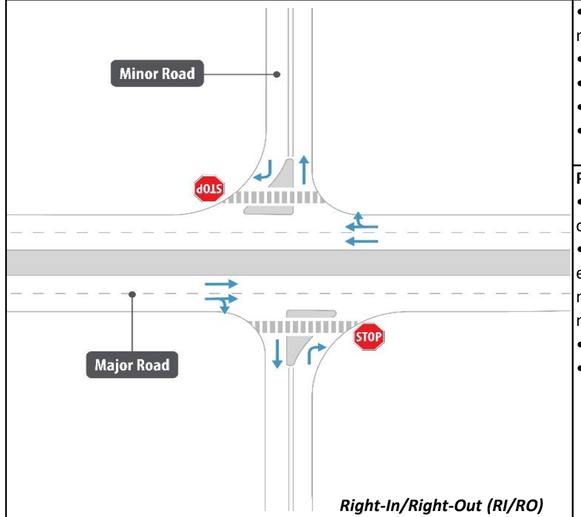
Minor Road Stop Control

Sample Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 *Minor Road Stop Control* A conventional intersection control type in which the minor road approaches are stop-controlled and the major road approaches do not encounter any traffic control devices.	• Clear distinction between major and minor roadway • Low minor road volume, especially for through and left-turn movements • Major road mobility is the primary concern • Signal warrants not met • All-way stop control warrants not met **Potential Benefits** • Major road delay is nonexistent or minimal • Inexpensive to install and maintain • Clearly defines which vehicles have priority • Low ROW impact **Potential Concerns** • Higher major road volumes reduce minor road gap availability and can result in high delays • Significant sight distance can be required when the major road operates at higher speeds • Potential for high-severity angle crashes, especially with higher major road speeds or volumes • Unwarranted or unneeded stop signs may have poor compliance • No accommodation for nonmotorists crossing major road	**Vehicles** Through and right-turn movements on the major road are free-flow, while left-turn movements are permissive. All minor road approaches are stop-controlled. **Pedestrians** Pedestrians crossing the minor road approaches have the ROW and are crossing at a stop-controlled location. The lack of signalization does not provide the pedestrian movement any protection across the major road. **Bicycles** Bicycles ride on the road in either a travel lane, bicycle lane (if available) or shoulder, unless multi-use path is present.	• Major road two-way volume ≤ 1,920 vph • Minor road two-way volume ≤ 480 vph Source: NCHRP Report 825, Exhibit 17. Note: The volume thresholds above assume a 50/50 directional distribution on each road, 10% left turns, 10% right turns, and 1 lane per approach (unless specified otherwise).	**4-leg Intersection** • 32 total conflict points • 16 crossing conflict points **3-leg Intersection** • 9 total conflict points • 3 crossing conflict points	• Highway Capacity Software (HCS) • Synchro • FHWA SPICE	**Reference Material** • Highway Capacity Manual (HCM) • Highway Safety Manual (HSM) • Unsignalized Intersection Improvement Guide (UIIG) **Other Considerations** • Least restrictive form of intersection control • Wide, open medians can be used for two-stage crossings

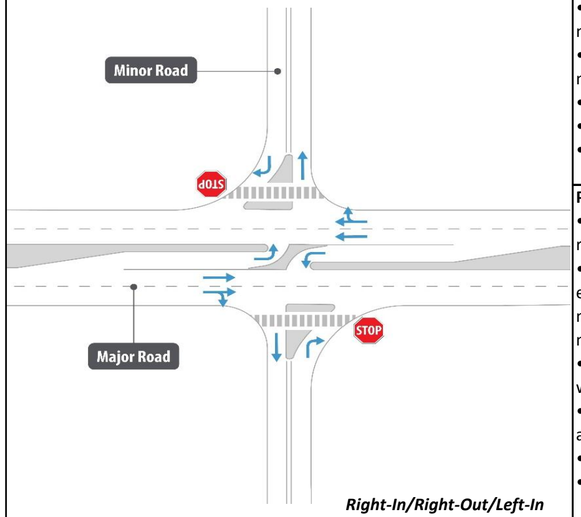
All-Way Stop Control

Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 *All-Way Stop Control* A conventional intersection control type in which every approach is stop-controlled with priority being assigned based on arrival order.	• Lower, balanced traffic volumes • ROW or sight distance constraints • All-way stop control warrants met • Signal warrants not met • Maintaining major road through movements as free flow is not the primary concern **Potential Benefits** • Improved safety • Inexpensive to install and maintain • Stop control provided for all nonmotorist crossings • Requires minimal ROW and sight distance **Potential Concerns** • Operationally inefficient under most conditions and increases delay to all legs of the intersection • Higher vehicle emissions due to required stopping • Lowest capacity of any intersection type • Providing for U-turns may be difficult or prohibited	**Vehicles** All vehicles are required to stop before proceeding through the intersection. **Pedestrians** All pedestrian crossings are located at the same place as the stop signs with pedestrians having the ROW. **Bicycles** Bicycles ride on the road in either a travel lane, bicycle lane (if available) or shoulder, unless multi-use path is present.	**Single Lane All-Way Stop** • 480 vph < major road two-way volume (all lanes) ≤ 1,050 vph • 260 vph < minor road two-way volume ≤ 660 vph • Total entering capacity, all approaches ≤ 1,200 vph **Multilane All-Way Stop** • 660 vph < major road two-way volume ≤ 1,360 vph • 260 vph < minor road two-way volume ≤ 800 vph • Total entering capacity, all approaches ≤ 1,800 vph Source: NCHRP Report 825, Exhibit 17 and 76. Note: The volume thresholds above assume a 50/50 directional distribution on each road, 10% left turns, 10% right turns, and 1 lane per approach (unless specified otherwise).	**4-leg Intersection** • 32 total conflict points • 16 crossing conflict points **3-leg Intersection** • 9 total conflict points • 3 crossing conflict points	• Highway Capacity Software (HCS) • Synchro	**Reference Material** • Highway Capacity Manual (HCM) • Highway Safety Manual (HSM) • Unsignalized Intersection Improvement Guide (UIIG) **Other Considerations** • AWSC may be appropriate as an interim solution

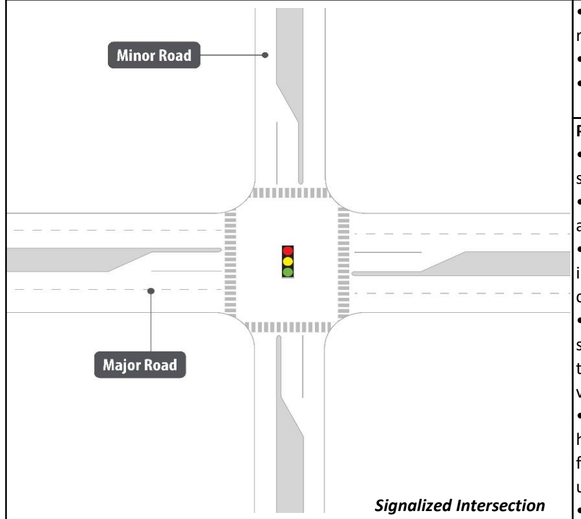
Right-In/Right-Out (RI/RO)

Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 *Right-In/Right-Out (RI/RO)* Left-turns from the major road and through and left-turns from the minor road are not permitted. The minor road approach is stop-controlled. This intersection type can apply to 3-leg and 4-leg intersections.	• History of angle crashes involving minor road through and left-turns and major road left-turns • Other intersections are nearby to facilitate restricted movements • Intersection encroaches on the influence area of an adjacent intersection • Signal warrants not met • All-way stop control warrants not met **Potential Benefits** • Crossing conflicts are eliminated so overall safety is increased • Operations at the intersection are enhanced due to the elimination of minor road through and left-turns and major road left-turns • Inexpensive to install and maintain • Minimal ROW impact **Potential Concerns** • Access at the intersection is severely reduced which is generally not favored by businesses • Adjacent intersections may be adversely affected as vehicles will be forced to execute turning maneuvers at locations other than the restricted access intersection • Travel time may increase for drivers wanting to make minor road left-turn and through movements and major road left-turn movements at this location • No accommodation for nonmotorists crossing major road	**Vehicles** The left-turn movement on the major road and through and left-turn movements on the minor road are prohibited. The minor road approach is stop-controlled. **Pedestrians** Pedestrians crossing the minor road approaches have the ROW and are crossing at a stop-controlled location. Pedestrians are not protected when crossing the major road. **Bicycles** Bicycles ride on the road in either a travel lane, bicycle lane (if available) or shoulder, unless multi-use path is present.	$\text{RT Capacity} = 1099.90e^{-0.00133v_{th}}$ RT Capacity is for the minor road right-turn. Equation derived from HCM, assuming two-lane major and minor roads, 2% heavy vehicles and no nonmotorists. v(th) is hourly volume of through traffic on the major road adjacent to the minor road right-turn.	**4-leg Intersection** • 4 total conflict points • 0 crossing conflict points **3-leg Intersection** • 2 total conflict points • 0 crossing conflict points	• Highway Capacity Software (HCS) • Synchro	**Reference Material** • Highway Capacity Manual (HCM) **Other Considerations** • Access restrictions like RI/RO may be more feasible in combination with nearby intersections that allow for U-turns

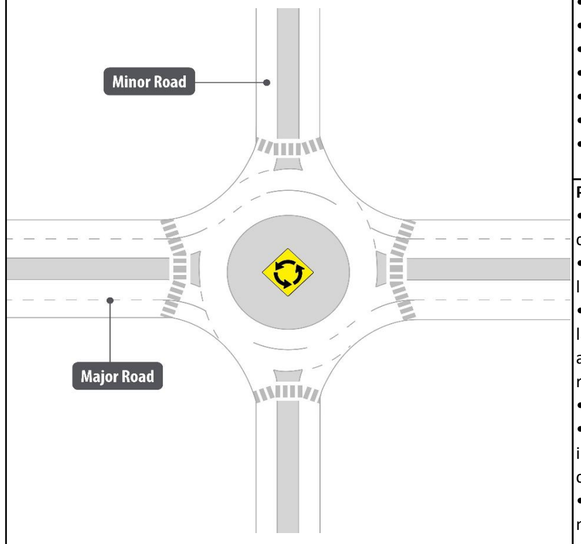
Right-In/Right-Out/Left-In (3/4 Access)

Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 *Right-In/Right-Out/Left-In (3/4 Access)* Through and left-turn movements out of the minor road are not permitted. This intersection type can apply to 3-leg and 4-leg intersections.	• History of angle crashes involving minor road through and left-turn movements • There is not a significant history of crashes involving the major road left-turn movements • Intersection encroaches on the influence area of an adjacent intersection • Signal warrants not met • All-way stop control warrants not met **Potential Benefits** • Crossing conflicts are significantly reduced so overall safety is improved • Operations at the intersection are enhanced due to the elimination of minor road through and left-turn movements • Provides more access than RI/RO which may be preferred by businesses • All movements from the mainline are maintained • Inexpensive to install and maintain • Minimal ROW impact **Potential Concerns** • Access at the intersection is reduced for vehicles exiting from the minor road • Adjacent intersections may be adversely affected as vehicles will be forced to execute turning maneuvers at locations other than the restricted access intersection • Travel time may increase for drivers wanting to make minor road left-turn and through movements at this location • No accommodation for nonmotorists crossing major road; however, 2-stage crossing is typically provided	**Vehicles** The through and left-turn movements on the minor road are prohibited. The minor road approaches are stop-controlled. **Pedestrians** Pedestrians crossing the major road are usually accommodated on a diagonal "Z" path from one corner of the intersection to the opposite corner. Pedestrian crossings are also located across the minor road. See FHWA-SA-14-070 for additional guidance on pedestrian treatments. **Bicycles** Bicycles ride on the road in either a travel lane, bicycle lane (if available) or shoulder, unless multi-use path is present. Side road through and left-turn movements can use the pedestrian crossings.	$\text{LT Capacity} = 1628.62e^{-0.00086v_{th}}$ $\text{RT Capacity} = 1099.90e^{-0.00133v_{th}}$ RT Capacity is for the minor road right-turn. Equation derived from HCM, assuming two-lane major and minor roads, 2% heavy vehicles and no nonmotorists. For LT Capacity, v(th) is hourly volume of through traffic on the major road that the left-turn movement crosses. For RT Capacity, v(th) is hourly volume of through traffic on the major road adjacent to the minor road right-turn.	**4-leg Intersection** • 10 total conflict points • 2 crossing conflict points **3-leg Intersection** • 5 total conflict points • 1 crossing conflict points	• Highway Capacity Software (HCS) • Synchro	**Reference Material** • Highway Capacity Manual (HCM) • Highway Safety Manual (HSM) • Restricted Crossing U-Turn Intersection Informational Guide (FHWA-SA-14-070)

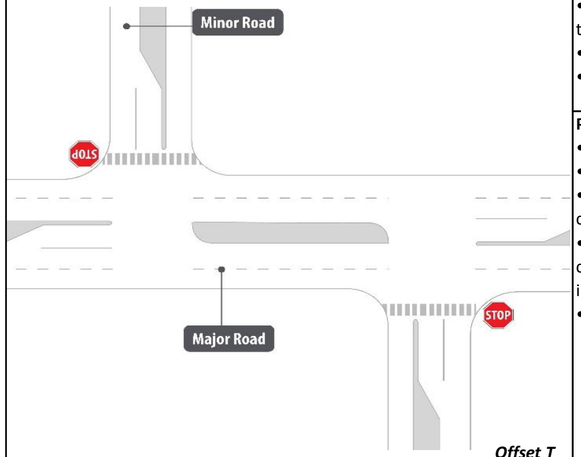
Signalized Intersection

Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 ***Signalized Intersection*** A conventional intersection control type in which each approach is controlled by a traffic signal.	• Available gaps are not adequate to complete desired movements under less restrictive control • Signal warrants met • Nearby intersections are signalized and coordination is possible **Potential Benefits** • Can be coordinated with other signals to provide desired progression • Flexibility can be achieved via timing adjustments • Adaptive control can be implemented along a signalized corridor/network • Pedestrians are assigned protected signal time to cross the road, rather than having to find gaps between vehicles • Most common form of control for higher volume intersections, so it is fully established and generally understood by all users • Can accommodate emergency vehicle and transit if pre-emption devices are installed **Potential Concerns** • Major road delay is often greater than it is under less restrictive control • Severe crashes can occur due to red light running or poor visibility of the signal displays • Dedicated turn lane requirements can result in wider approaches, meaning longer pedestrian crossings and additional ROW requirements • Can experience extensive queuing, especially with longer cycle lengths • Costly to install • Requires considerable maintenance • Decreased efficiency with high left-turning volumes • Providing for U-turns may be difficult or prohibited	**Vehicles** Vehicular movements on each approach are controlled through protected, permissive, or prohibited lights on the traffic signal. **Pedestrians** Pedestrian phases can be built into the signal timing to allow for permissive pedestrian crossings at the designated crosswalks. Accessible pedestrian signals and pushbuttons can be utilized. **Bicycles** Bicycles ride on the road in either a travel lane, bicycle lane (if available) or shoulder, unless multi-use path is present.	• 920 vph < major road two-way volume ≤ 2,000 vph • 260 vph < minor road two-way volume ≤ 800 vph Source: NCHRP Report 825, Exhibit 17. Note: The volume thresholds above assume a 50/50 directional distribution on each road, 10% left turns, 10% right turns, and 1 lane per approach (unless specified otherwise). • Critical lane volume ≤ 1,500 vphpl	**4-leg Intersection** • 32 total conflict points • 16 crossing conflict points **3-leg Intersection** • 9 total conflict points • 3 crossing conflict points	• FHWA CAP-X (sketch-planning level) • Highway Capacity Software (HCS) • Synchro • FHWA SPICE	**Reference Material** • Highway Capacity Manual (HCM) • Highway Safety Manual (HSM) • Signalized Intersection Guide, 2nd Edition (FHWA-SA-13-027) **Other Considerations** • Preferred control when railroad pre-emption is required

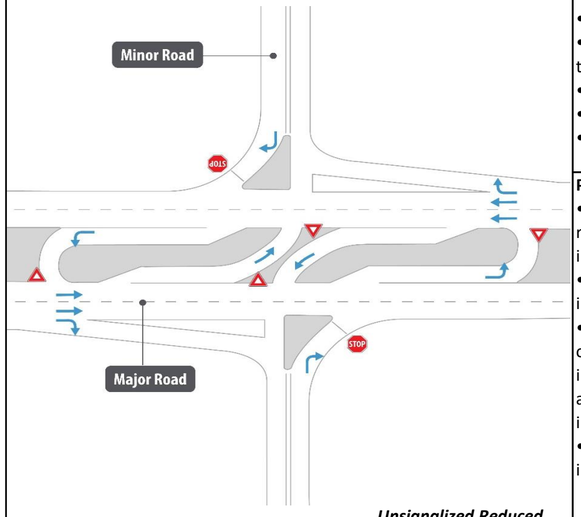
Roundabout

Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 ***Roundabout*** Yield control of all entering vehicles, channelized approaches, and horizontal curvature and roadway elements to induce reduced vehicle speeds. There are three main types of roundabouts: mini, single-lane, and multilane.	• Relatively balanced traffic volumes or heavy left-turn traffic • Signal or all-way stop control warrants met • Significant crash history, especially angle crashes • Unconventional geometry (5 or more legs, high skew, etc.) • Large number of U-turn movements • Limited right of way for lane widening between intersections • Desired speed reduction or traffic calming • Transition between two different land uses or speed zones **Potential Benefits** • Significantly reduces risk of serious crashes via geometry • Lower vehicle emissions due to limited stopping and idling • Can reduce number of approach lanes, and therefore approach width and ROW requirements along the roadways • Can have traffic calming effects • Can accommodate closely spaced intersections better than other traffic control options • Allows for convenient U-turn movement • Pedestrian crossings are shorter • Usually reduced delay compared to signalized control • Lower long-term costs for operations and maintenance • Comparable if not greater capacity than other alternatives **Potential Concerns** • Coordination not possible and may hinder efficient traffic flow in a coordinated signal system • May require additional ROW at the intersection to accommodate the center island and circulating roadway • No flexibility in assigning priority • All vehicles are required to slow down from free-flow speeds • Can see operations deteriorate rapidly under congested conditions • Pedestrian crossings are uncontrolled • Typically requires additional features such as landscaping, lighting, and truck aprons • Moderate construction costs	**Vehicles** Vehicles approaching the intersection must yield to vehicles circulating counterclockwise within the roundabout. **Pedestrians** Pedestrian crossings are located only across the legs of the roundabout, typically separated from the circulatory roadway by at least one vehicle length (minimum of 20 feet). **Bicycles** Bicyclists ride in the roadway with vehicles, shoulders or transition to multi-use paths via bicycle ramps (if present). Bike lanes should not be used at roundabouts.	**Single Lane Roundabout** • Sum of entering and conflicting volumes ≤ 1,000 vph - Likely sufficient • 1,000 vph < sum of entering and conflicting volumes ≤ 1,300 vph - May be sufficient based on more detailed analysis or two-lane entry may be needed **Multilane Roundabout** • 1,300 vph < sum of entering and conflicting volumes ≤ 1,800 vph - Likely sufficient • Sum of entering and conflicting volumes > 1,800 vph - More than two entering lanes may be required, so a more detailed capacity evaluation should be conducted to verify lane numbers and arrangements Source: NCHRP Report 672, Exhibit 3-14.	**3-leg Intersection** • 6 total conflict points • 0 crossing conflict points **4-leg Intersection** • 8 total conflict points • 0 crossing conflict points **5-leg Intersection** • 10 total conflict points • 0 crossing conflict points	• FHWA CAP-X (sketch-planning level) • Highway Capacity Software (HCS) • Synchro • Sidra with US HCM Model • FHWA SPICE	**Reference Material** • Highway Capacity Manual (HCM) • Highway Safety Manual (HSM) • Roundabouts: An Informational Guide, 2nd Edition (NCHRP 672) • Roundabouts Technical **Other Considerations** • Accommodation of larger vehicles, including OSOW, can be challenging but may be addressed with unique design considerations • Consider need for expandable design (e.g., one lane to two lanes)

Offset T-Intersection

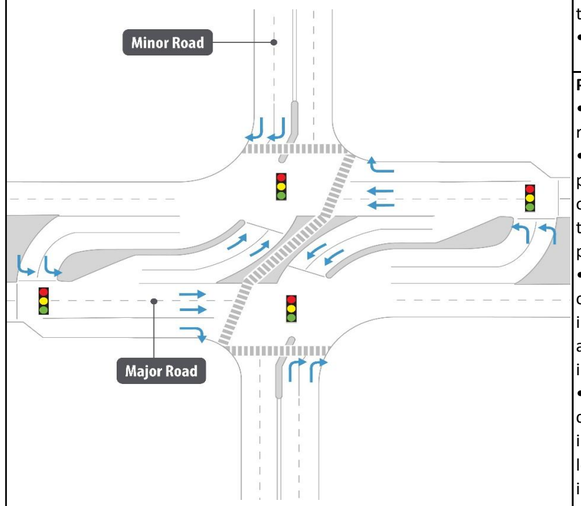
Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 *Offset T* At an offset T-intersection, direct minor road through movements are not possible. Instead, vehicles must make a left onto the major road and then a right onto the other minor road or vice versa. Note that the preferred offset option is shown above (a minor road through movement completed via a right-turn from the minor road followed by a left-turn is less desirable).	• Existing four-leg intersection with a history of angle crashes for minor road through vehicles • Low minor road volumes, especially for the minor road through movement • Intersection skew present **Potential Benefits** • Reduces crossing conflicts • Can correct intersection skew • Can potentially reduce angle collisions • Increase to overall intersection capacity versus a standard four-leg intersection • Low cost to maintain **Potential Concerns** • ROW is required to accommodate the offset between the two intersections • Rear-end crashes could increase due to low vehicle speeds as minor road through movements require a series of two consecutive turns • Design could introduce delay to the minor through movement relative to the offset distance • Moderate construction costs • No accommodation for nonmotorists crossing major road	**Vehicles** Through movements on the minor roads must turn left onto the main road and then right onto the opposite minor road, or vice versa. **Pedestrians** Pedestrians crossing the minor road approaches have the ROW and are crossing at a stop-controlled location. Pedestrian crossings of the major road are unprotected and located to the outside of the minor roads. **Bicycles** Bicycles ride on the road in either a travel lane, bicycle lane (if available) or shoulder, unless multi-use path is present.		• 18 total conflict points • 6 crossing conflict points	• Highway Capacity Software (HCS) • Synchro • SimTraffic • Vissim	**Reference Material** • Highway Capacity Manual (HCM) • Highway Safety Manual (HSM) **Other Considerations** • The location of offset intersections relative to each other determines whether minor road through vehicles make a left or right-turn from the mainline. Depending on the situation, one may be preferable to the other. • Offset distance is dictated by the through and left-turn volumes present at the intersections, sight distance considerations, and speed limit • Can be used at both unsignalized and signalized intersections

Unsignalized Reduced Conflict Intersection (RCI)

Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 ***Unsignalized Reduced Conflict Intersecion (RCI)*** An unsignalized intersection design that restricts left-turn and through movements out of the minor road and redirects them downstream on the major road to make a U-turn in the median opening. Minor road approaches are stop-controlled.	• History of angle crashes, especially far-side • Located on a high-speed, divided facility • Located in a relatively rural area with significant intersection spacing • Low minor road through and left-turn volumes and heavy major road through and left-turn volumes • Areas where median widths are greater than 40 feet • Signal warrants not met • All-way stop control warrants not met **Potential Benefits** • Crossing conflicts are significantly reduced, so overall safety may be improved • Vehicles only focus on finding a gap in one direction of traffic at a time • U-turns are handled at median openings adjacent to the main intersection and will not route additional traffic to adjacent intersections • Increases capacity at the main intersection **Potential Concerns** • Out-of-direction travel for side road left-turn and through movements • Requires wide median or outside ROW at U-turn crossover • Requires a longer, two-stage pedestrian crossing with potential for pedestrian way-finding challenges • Direct access to the major road between the main intersection and the U-turns is typically removed • Trucks with heavy load can have difficulty getting up to speed following a U-turn before an opposing vehicle within sight distance has caught up to them • Higher initial construction cost and potential for higher maintenance cost compared to conventional intersection	**Vehicles** Left-turns and through movements from the minor road are required to turn right onto the main road and then make a permissive U-turn maneuver at one-way median openings 800 feet ± 200 feet away from the main intersection. Minor road left-turn and through movements then travel through or turn right, respectively, at the main intersection. **Pedestrians** Pedestrians crossing the major road are usually accommodated on a diagonal "Z" path from one corner of the intersection to the opposite corner. Pedestrian crossings are also located across the minor road. See FHWA-SA-14-070 for additional guidance on pedestrian treatments. **Bicycles** Bicycles ride on the road in either a travel lane, bicycle lane (if available) or shoulder, unless multi-use path is present. Side road through and left-turn movements can use the pedestrian crossings.	• Minor road two-way volume ≤ 5,000 vpd (or 450 vph) Source: FHWA Restricted Crossing U-Turn Informational Guide, Exhibit 5-7.	• 14 total conflict points • 2 crossing conflict points	• FHWA CAP-X (sketch-planning level) • Highway Capacity Software (HCS) • Synchro • SimTraffic • Vissim • FHWA SPICE	**Reference Material** • Highway Capacity Manual (HCM) • Highway Safety Manual (HSM) • Restricted Crossing U-Turn Intersection (FHWA-HRT-09-059) • Restricted Crossing U-Turn Intersection Informational Guide (FHWA-SA-14-070) • Synthesis of the Median U-Turn Intersection Treatment (FHWA-HRT-07-033) • Alternative Intersections Informational Report (AIIR) **Other Considerations** • A “loon” at the U-turn may be required to accommodate the turning path of larger vehicles **Other Names** • Restricted Crossing U-Turn • J-Turn

Signalized Reduced Conflict Intersection (RCI)

Illustration & Description



Signalized Reduced Conflict Intersection (RCI)

A signalized intersection design that restricts left-turn and through movements out of the minor road and redirects them downstream on the major road to make a U-turn in the median opening.

When to Consider

- History of angle crashes, especially far-side
- Located on suburban or rural road
- Low minor road through and left-turn volumes and heavy major road through and left-turn volumes
- Areas where median widths are greater than 40 feet

Potential Benefits

- Crossing conflicts are significantly reduced, so overall safety is improved
- Movements are served with protected signal phasing or only focus on finding a gap in one direction of traffic at a time, reducing crash potential.
- U-turns are handled at median openings adjacent to the main intersection and will not route additional traffic to adjacent intersections
- Fewer signal phases with 4 phases (2 critical phases) at the main intersection, allowing for shorter cycle lengths, which permit more flexibility in traffic signal progression
- Traffic signals in one major road direction can run separate cycle lengths than the traffic signals on the other major road direction
- Reduces delay on the major road and increases capacity at the main intersection

Potential Concerns

- Out-of-direction travel for side road left-turn and through movements
- Requires wide median or outside ROW at U-turn crossover
- Requires a longer, two-stage pedestrian crossing with potential for pedestrian way-finding challenges
- Direct access to the major road between the main intersection and the U-turns is typically removed
- Trucks with heavy load can have difficulty getting up to speed following a U-turn before an opposing vehicle within sight distance has caught up to them
- Higher initial construction cost and potential for higher maintenance cost compared to conventional intersection

Mode Accommodations

Vehicles

Left-turns and through movements from the minor road are required to turn right onto the main road and then make a permissive U-turn maneuver at one-way median openings 600 feet ± 200 away from the main intersection. Minor road left-turn and through movements then travel through or turn right, respectively, at the main intersection.

Pedestrians

Pedestrians crossing the major road are usually accommodated on a diagonal "Z" path from one corner of the intersection to the opposite corner. Pedestrian crossings are also located across the minor road. See FHWA-SA-14-070 for additional guidance on pedestrian treatments.

Bicycles

Bicycles ride on the road in either a travel lane, bicycle lane (if available) or shoulder, unless multi-use path is present. Side road through and left-turn movements can use the pedestrian crossings.

Volume Thresholds

- Not suitable for an intersection of two arterials
- Minor road two-way volume ≤ 25,000 vpd (or 2,250 vph)

Source: FHWA Restricted Crossing U-Turn Informational Guide, Exhibit 5-7.

- Critical lane volume ≤ 1,500 vphpl
- U-turn volume ≤ 450 vphpl

Vehicular Conflict Points

- 14 total conflict points
- 2 crossing conflict points

Recommended Analysis Tools

- FHWA CAP-X (sketch-planning level)
- Highway Capacity Software (HCS)
- Synchro
- SimTraffic
- Vissim
- FHWA SPICE

Supporting Information and Design Criteria

Reference Material

- Highway Capacity Manual (HCM)
- Restricted Crossing U-Turn Intersection (FHWA-HRT-09-059)
- Restricted Crossing U-Turn Intersection Informational Guide (FHWA-SA-14-070)
- Synthesis of the Median U-Turn Intersection Treatment (FHWA-HRT-07-033)
- Alternative Intersections Informational Report (AIIR)

Other Considerations

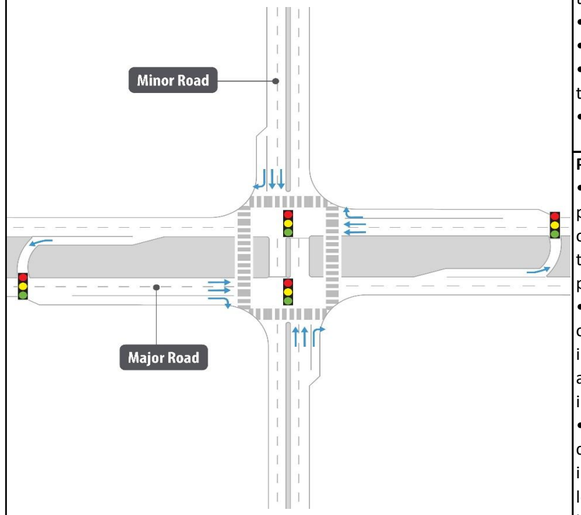
- A “loon” at the U-turn may be required to accommodate the turning path of larger vehicles

Other Names

- Restricted Crossing U-Turn
- Superstreet

Median U-Turn (MUT)

Illustration & Description



Median U-Turn (MUT)

A median U-turn is an intersection treatment that eliminates direct left-turns at signalized intersections from major and minor approaches and replaces them with U-turns on the major or minor road. A partial median U-turn allows left-turns from the minor road.

When to Consider

- History of angle crashes, especially far-side and involving the major road left-turn movements
- Located on a high-speed, divided facility
- Located in a relatively rural area with significant intersection spacing
- Intersections with heavy through traffic volumes and moderate left-turn traffic volumes
- Area where median widths are greater than 40 feet

Potential Benefits

- Movements are served with protected signal phasing or only focus on finding a gap in one direction of traffic at a time, reducing crash potential
- U-turns are handled at median openings adjacent to the main intersection and will not route additional traffic to adjacent intersections
- Fewer signal phases with 4 phases (2 critical phases) at the main intersection, allowing for shorter cycle lengths, which permit more flexibility in traffic signal progression
- Reduces delay on the major road compared to a conventional signalized intersection and increases capacity at the main intersection
- Better progression on the major road

Potential Concerns

- Out-of-direction travel for left-turn movements
- Requires wide median or outside ROW at U-turn crossover
- May require a longer, two-stage pedestrian crossing
- Direct access to the major road between the main intersection and the U-turns is typically removed
- Trucks with heavy load can have difficulty getting up to speed following a U-turn before an opposing vehicle within sight distance has caught up to them
- Higher initial construction cost and potential for higher maintenance cost compared to conventional intersection

Mode Accommodations

Vehicles

Left-turns must utilize a combination of a U-turn downstream of the intersection and right-turn at the main intersection to complete the maneuver. The U-turn is located at one-way median openings 400-800 feet away from the main intersection.

Pedestrians

Crosswalks are in locations similar to a conventional intersection with crossings often being in two-stages.

Bicycles

Bicycles ride on the road in either a travel lane, bicycle lane (if available) or shoulder, unless multi-use path is present. Bicycles have the option to use the pedestrian crosswalks or the U-turn crossovers in a manner similar to vehicles.

Volume Thresholds

- 300 vph < Major road approach volume ≤ 1,900 vph
- 100 vph < Minor road approach volume ≤ 500 vph

Source: Gyawali, Sunil, "A New Decision Making Approach for Indirect Left Turn Treatments by Utilizing Decision Assistance Curves" (2014).

- Critical lane volume ≤ 1,500 vphpl
- U-turn volume ≤ 450 vphpl

Vehicular Conflict Points

- 16 total conflict points
- 4 crossing conflict points

Recommended Analysis Tools

- FHWA CAP-X (sketch-planning level)
- Highway Capacity Software (HCS)
- Synchro
- SimTraffic
- Vissim
- FHWA SPICE

Supporting Information and Design Criteria

Reference Material

- Highway Capacity Manual (HCM)
- Median U-Turn Intersection Informational Guide (FHWA-SA-14-069)
- Synthesis of the Median U-Turn Intersection Treatment (FHWA-HRT-07-033)
- Alternative Intersections Informational Report (AIIR)

Other Considerations

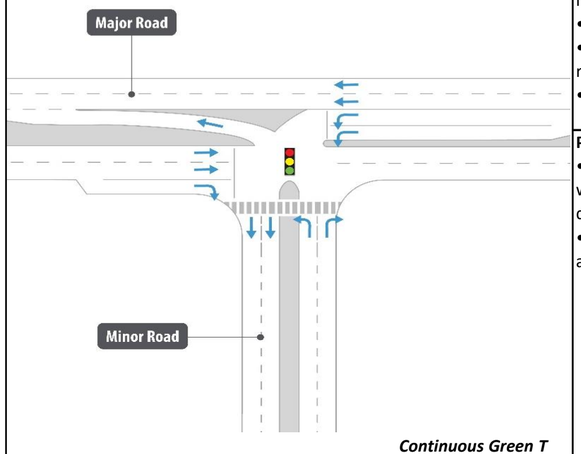
- A “loon” at the U-turn may be required to accommodate the turning path of larger vehicles

Other Names

- Michigan Left

Continuous Green T-Intersection

Illustration & Description



Continuous Green T

A continuous green T-intersection is a signalized, 3-leg intersection that features raised channelization that separates the top through movement from the other movements of the intersection. This enables the top through movement to operate free-flowing with no conflicting movement.

When to Consider

- Intersection has three legs, typically two major road approaches and one minor road approach
- Intersection with heavy through traffic volumes on the major road
- Intersection with moderate to low left-turn traffic volumes on the minor road
- Signal warrants are met

Potential Benefits

- One of the major road movements will be free-flow, reducing potential delay
- Improved traffic signal progression and reduced corridor travel times

Potential Concerns

- The minor road left-turn movement joins major road through traffic from the left, typically with a lane add followed by a merge maneuver, which is contrary to driver expectations
- No pedestrian crossing of arterial unless full signal is provided
- Potential need for additional ROW
- Moderate construction and maintenance costs

Mode Accommodations

Vehicles

Minor road left-turns are channelized, allowing a continuous green signal to be displayed to the top mainline through movement.

Pedestrians

Permissive pedestrian crossings are provided across the minor road at the signal. Due to the continuous flowing nature of through movements on one of the major approaches, pedestrian movements across the mainline should be accommodated at an adjacent intersection or via a mid-block crossing, as appropriate.

Bicycles

Bicycles ride on the road in either a travel lane, bicycle lane (if available) or shoulder, unless multi-use path is present.

Volume Thresholds

- Critical lane volume ≤ 1,500 vphpl

Vehicular Conflict Points

- 9 total conflict points
- 3 crossing conflict points

Recommended Analysis Tools

- Highway Capacity Software (HCS)
- Synchro
- SimTraffic
- Vissim

Supporting Information and Design Criteria

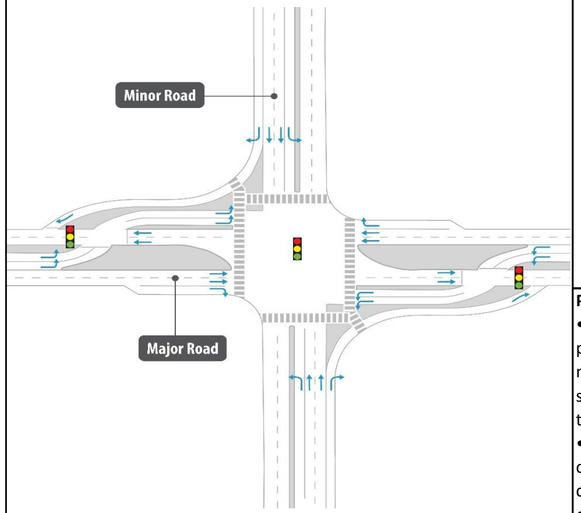
Reference Material

- Highway Capacity Manual (HCM)
- Continuous Green T-Intersections Case Study (FHWA-SA-09-016)
- Continuous Green T-Intersections Technical Summary (FHWA-HRT-19-032)

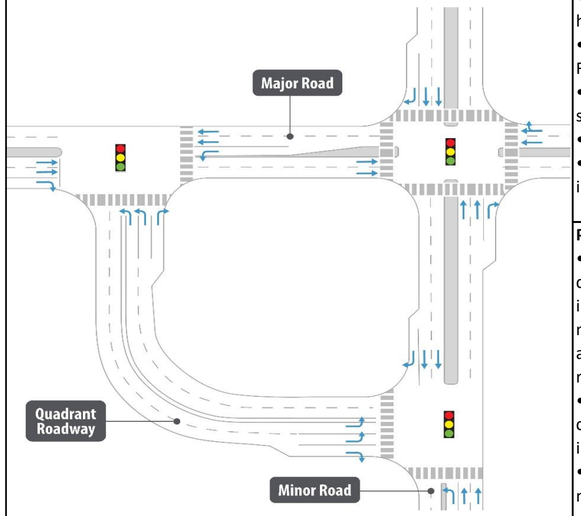
Other Considerations

- Analysis of operations can be difficult given software limitations

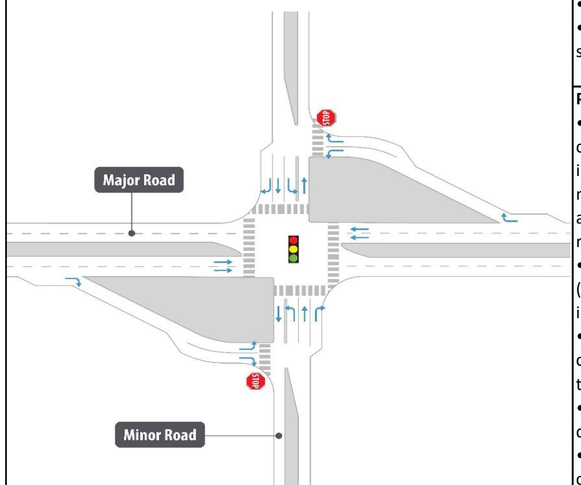
Displaced Left-Turn (DLT)

Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 ***Displaced Left-Turn (DLT)*** A signalized intersection where one or more left-turn movements are relocated to the other side of the opposing traffic lanes. These movements travel parallel to the opposing lanes and complete the left-turn movement simultaneously with the through movements, eliminating the left-turn phase for the approach at the main intersection. A full displaced left-turn intersection includes crossovers for left-turns on both the major and minor roads while a partial displaced left-turn intersection includes crossovers for left-turns on either the major or minor roads	• High volume of traffic and heavy left-turn volumes • Balanced traffic flow • Urban or suburban setting • Intersection operating at (or expected to reach) capacity for a traditional signalized intersection • Signal warrants are met **Potential Benefits** • Additional green time can be provided to through movements and non-displaced left-turn movements, since the phase for the displaced left-turn is eliminated • Capacity can be increased and delay can be reduced compared to a conventional signalized intersection • Fewer conflict points can result in a safer intersection •Less expensive than a grade-separated interchange and can be constructed faster **Potential Concerns** • More ROW is required to accommodate the larger footprint • This intersection type may be unfamiliar to drivers • Coordination with other signals could be negatively impacted • Access may be restricted within the vicinity of the intersection • Additional signals are needed • U-turn movements may be eliminated at the intersection • Pedestrian crossings may require median refuge and two stage crossing • Moderate cost to maintain	**Vehicles** Left-turn movements at the intersection are relocated to the other side of the opposing roadway, eliminating the left-turn phase for the approach at the main intersection. Left-turns are brought across the opposing travel lanes via a signalized intersection generally 300-500 ft upstream of the main intersection. Left-turn vehicles then travel on a new roadway parallel to the opposing lanes and execute the left-turn maneuver simultaneously with the through traffic at the main intersection. **Pedestrians** Pedestrians crossing at a DLT intersection may be required to cross more travel lanes than at a conventional intersection, and direction of traffic in those lanes may be counterintuitive to pedestrians. Many DLT intersections are set up for pedestrians to cross in multiple stages with median islands providing refuge. See FHWA-SA-14-068 for additional guidance on pedestrian treatments at DLTs. **Bicycles** Bicyclists can be provided on the road using marked bicycle lanes. However, special care is required for DLT intersections to consider and address how bicyclists will interact with different paths of vehicles. Multi-use paths can also be accommodated if they are designed to cross at appropriate locations, typically the same locations as the crosswalks. See FHWA-SA-14-068 for additional guidance on bicycle treatments at DLTs.	• A full DLT intersection (four approaches with DLT) with 2-3 lanes per approach can handle about 12,000 vph • A partial DLT intersection (two approaches with DLT) with 2-3 lanes per approach can accommodate up to 10,000 vph Source: Innovative Intersections: Overview and Implementation Guidelines. Community Planning Association of Southwest Idaho. --- • Critical lane volume ≤ 1,500 vphpl • Left-turn lane volume at crossovers ≤ 600 vphpl Note: Left-turn lane volume at crossovers based on critical lane volume of 1,500 vphpl, 50/50 signal phasing distribution and 20% reduction to left-turn capacity. --- Generally could be considered when: • Major road volume > 2,000 vph • Minor road volume > 300 vph Source: Gyawali, Sunil, "A New Decision Making Approach for Indirect Left Turn Treatments by Utilizing Decision Assistance Curves" (2014).	**3-leg Intersection (1 crossover on major road)** • 9 total conflict points • 3 crossing conflict points **4-leg Intersection (2 crossovers on major road)** • 30 total conflict points • 14 crossing conflict points **4-leg Intersection (2 crossovers on major road and 2 crossovers on minor road)** • 28 total conflict points • 12 crossing conflict points	• FHWA CAP-X (sketch-planning level) • Highway Capacity Software (HCS) • Synchro • SimTraffic • Vissim • FHWA SPICE	**Reference Material** • Highway Capacity Manual (HCM) • Displaced Left Turn Intersection Informational Guide (FHWA-SA-14-068) • Alternative Intersections Informational Report (AIIR) **Other Considerations** • It is possible to have a corridor of DLT intersections **Other Names** • Continuous Flow Intersection (CFI) • Crossover Displaced Left-Turn Intersection (XDL)

Quadrant Roadway

Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 ***Quadrant Roadway*** A quadrant roadway intersection is intended to eliminate all direct left-turn movements from the main intersection by rerouting them to a connector roadway located in one quadrant.	• The intersection has a high volume of through movements • The intersection has low to moderate left-turn volumes or only has one heavy left-turn movement • There is an existing roadway that can be used as the connector roadway or ROW available to construct a connector roadway • A single, large, congested intersection in the middle of a coordinated signal system • At skewed intersections • As a temporary measure when there are plans for a grade separated interchange **Potential Benefits** • Congestion can be reduced and capacity can be increased at the main intersection by removing the left-turn movements (all left-turn movements at the main intersection can be relocated with one quadrant roadway) • Fewer signal phases with 4 phases (2 critical phases) at the main intersection • Reduces and spreads out the number of points where vehicles may cross paths • Coordination of three signalized intersections improves corridor travel times on both the major and minor roads **Potential Concerns** • A large amount of ROW is required, especially if used in more than one quadrant • Additional intersections are created and turning movements become more complex • Extra costs may be required to build the connecting roadway • The intersection area can be difficult to sign and confusing or unexpected for unfamiliar drivers • Out of direction travel for some movements •U-turn movements may be eliminated at the main intersection •Moderate to high cost to maintain	**Vehicles** All left-turns at the main intersection are prohibited and rerouted to use a connector (quadrant) roadway approximately 500 ft from the main intersection. The main intersection operates with two critical phases and the connector road intersections operate with three critical phases. **Pedestrians** Depending on the desired inbound and outbound sidewalks, some pedestrians are required to cross an extra road to make their desired movement compared to a conventional signalized intersection. The two-phase signal operation reduces the delay incurred by pedestrians at each crossing of the main intersection. **Bicycles** Left-turning bicyclists have the choice to follow the vehicular paths on the connector road or the crossing paths of pedestrians at the main intersection.	• Critical lane volume ≤ 1,500 vphpl	• 30 total conflict points • 10 crossing conflict points	• FHWA CAP-X (sketch-planning level) • Synchro • SimTraffic • Vissim	**Reference Material** • Highway Capacity Manual (HCM) • FHWA Quadrant Roadway Intersection Informational Guide (FHWA-SA-19-029) • FHWA Quadrant Roadway Intersection Technical Summary (FHWA-HRT-09-058) • Alternative Intersections Informational Report (AIIR)

Jughandle

Illustration & Description	When to Consider	Mode Accommodations	Volume Thresholds	Vehicular Conflict Points	Recommended Analysis Tools	Supporting Information and Design Criteria
 ***Jughandle*** A signalized intersection that uses at-grade ramp connectors between intersecting roadways to facilitate indirect left-turns or U-turns. Diagonal connectors may be placed upstream of the cross road or loop connectors may be placed downstream of the cross road.	• High volume of through movements and left-turns on the major road • A single, large, congested intersection in the middle of a coordinated signal system **Potential Benefits** • Congestion can be reduced and capacity can be increased at the main intersection by removing the left-turn movements (one left-turn movement at the main intersection can be relocated with each jughandle) • Fewer signal phases with 4-6 phases (2-3 critical phases) at the main intersection • May provide safer pedestrian crossing opportunities in comparison to high speed interchange ramps • Pedestrian crossing distance and delay may be reduced • Fewer conflict points than a conventional signal **Potential Concerns** • A large amount of ROW is required • Additional intersections are created and turning movements become more complex • The intersection area can be difficult to sign and confusing or unexpected for unfamiliar drivers • Out-of-direction travel for left-turn movements • Ramp diverges may create higher speed conflicts between bicyclists and motor vehicles • Transit stops may need to be relocated outside the influence area of the intersection • Moderate to high costs to construct and maintain	**Vehicles** Vehicles attempting to make a left-turn or U-turn utilize a connector ramp either upstream (short diamond-style ramp) or downstream (loop-style ramp) to facilitate their movement. **Pedestrians** Depending on the desired inbound and outbound sidewalks, some pedestrians may be required to cross one additional road compared to a conventional signalized intersection. If pedestrians do not interact with the quadrant where a jughandle is located, there is no notable difference compared to a conventional signalized intersection. **Bicycles** Left-turning bicyclists have the choice to follow the vehicular paths or the crossing paths of pedestrians at the main intersection.	• 1,900 vph < Major road volume ≤ 2,300 vph; • Minor road volume ≤ 350 vph Source: Gyawali, Sunil, "A New Decision Making Approach for Indirect Left Turn Treatments by Utilizing Decision Assistance Curves" (2014). Note: The volume thresholds above assume a 60/40 directional distribution on the major road, 15% left turns, and 1 lane per approach. • Critical lane volume ≤ 1,500 vphpl	**3-leg Jughandle** • 10 total conflict points • 4 crossing conflict points **4-leg with Direct Jughandles on Major Road** • 26 total conflict points • 10 crossing conflict points **4-leg with Indirect (loop) Jughandles on Major Road** • 24 total conflict points • 8 crossing conflict points	• Synchro • SimTraffic • Vissim • FHWA SPICE	**Reference Material** • Highway Capacity Manual (HCM) • Alternative Intersections Informational Report (AIIR)