

## NORTH CAROLINA

Department of Transportation



# Updated Charts Showing the Safest Feasible Intersection Design

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# Selecting an Intersection Design

- We have funding to improve an intersection
- We have a traffic forecast
- There are several design alternatives
- We can do modelling to estimate travel times for each alternative
- We can see what fits
- Before we choose an alternative, shouldn't we also consider safety?



# Happily, We Live in the Golden Age of CMFs

- Crash modification factor (CMF)
  - Before crash freq \* CMF = after crash freq
- Hundreds of millions of dollars on safety research during past 25 years
- Thousands of CMFs stored at the Clearinghouse at UNC-CH
  - Hundreds of countermeasures
  - Variety of crash types, location types, etc.
  - Quality of study ratings

# Let's Start Using Our CMFs

- For a given combination of major and minor street size and demand, what are the feasible intersection designs?
- For those feasible designs, which has the lowest CMF?
- Compile for all combinations
  - Create safest feasible intersection design (SAFID) charts
- First published in ITE Journal May 2020
  - This is an update
  - New CMFs, greater detail

# Good Clearinghouse CMFs for Intersections

Changing from...	Changing to...	Average CMF for all crashes	Average CMF for injury crashes
Two-way stop control (TWSC)	All-way stop control (AWSC)	0.32	0.28
	Conventional signal	0.81	0.74
	Mini roundabout	0.83	0.41
	Full-size one-lane roundabout	0.51	0.16
	Unsignalized reduced conflict intersection (RCI)	0.58	0.42
	Right-in-right-out (RIRO)	0.55	0.20
Conventional signal	Full-size one-lane roundabout	0.74	0.45
	Two-lane roundabout	0.89	0.54
	Signalized RCI	0.85	0.78
	Median u-turn (MUT)	0.63	0.77
	Partial continuous flow int. (CFI)	0.88	0.86

- We now have a pretty full set of good intersection CMFs!

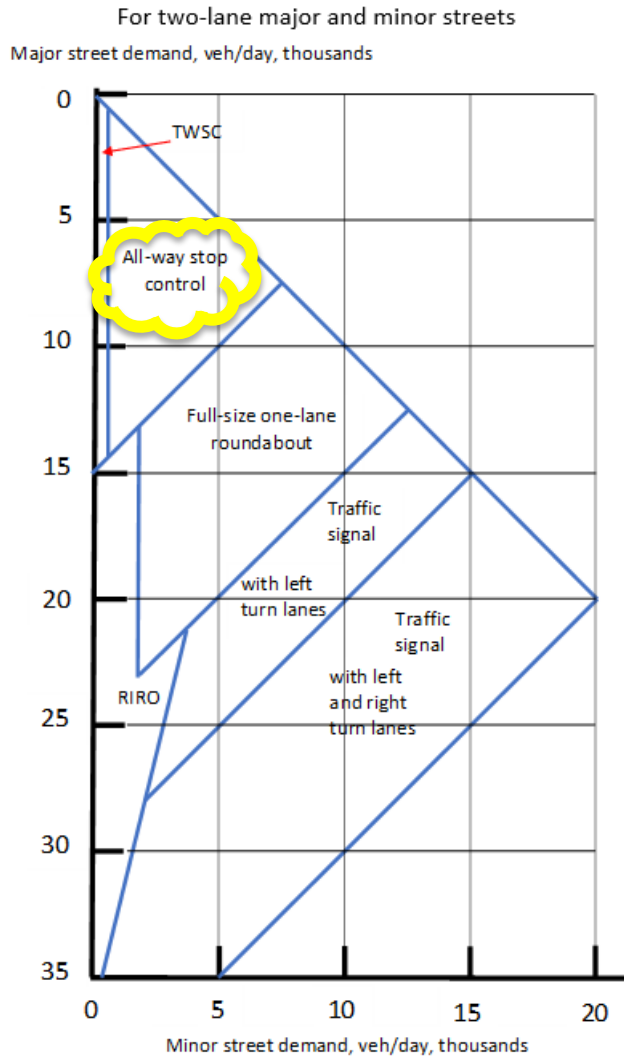
# Some Feasibility Rules

Design	Parameter	Limit, vpd
TWSC	Major street demand	< 14,000
AWSC	Total entering demand	< 15,000
RIRO	Minor street demand	< 1,000 to 5,000
Unsignalized RCI	Minor street demand	< 2,000 to 15,000
Signalized RCI	Minor street demand	< 25,000
One-lane roundabout	Total entering demand	< 25,000
Two-lane roundabout	Total entering demand	< 45,000

# Overall SAFID Chart

Major street number of through lanes	Minor street number of through lanes		
	Two	Four	Six or eight
Two	Mostly AWSC and one-lane full-size roundabout; see Figure 1	n/a	n/a
Four	Unsignalized RCI and MUT; see Figure 2	MUT for total crashes; two-lane roundabout and MUT for injury crashes, see Figure 3	n/a
Six	Unsignalized RCI and MUT; see Figure 4	MUT	MUT
Eight	Unsignalized RCI and MUT (similar to Fig. 4)	MUT	MUT

# Safest Feasible Small Intersection— All-Way Stop Control (Fig. 1)





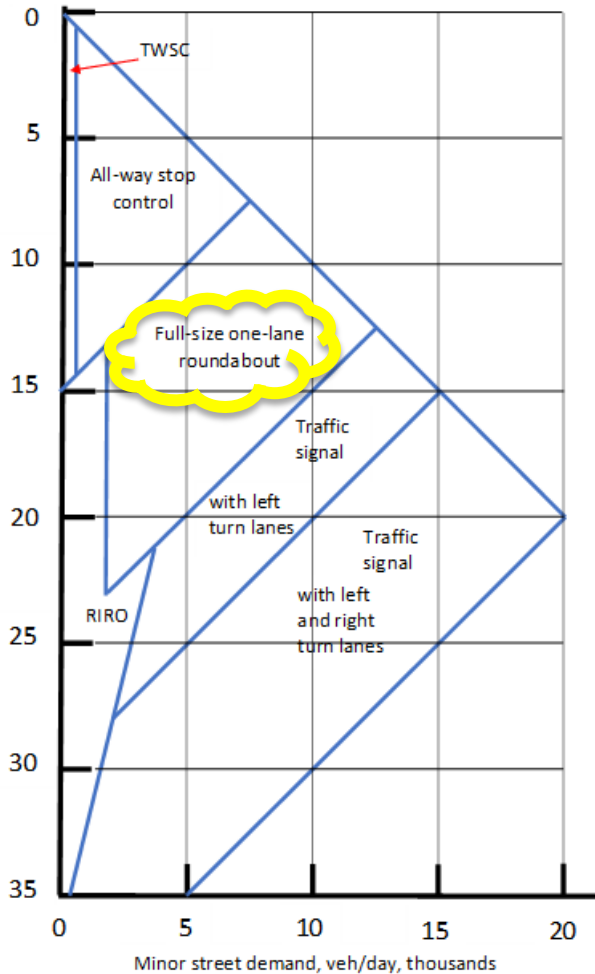
# All-Way Stop Control

- Travel efficiency
  - Typically about 10 sec/veh more delay for major street, larger reduction for minor street
- Cost
  - \$20,000 per site at NCDOT, benefit/cost 83:1
- No major barriers
  - MUTCD “warrants”, unbalanced demands, trucks, high speeds, primary routes, peds

# Safest Feasible Midsize Intersection— One-Lane Roundabout (Fig. 1)

For two-lane major and minor streets

Major street demand, veh/day, thousands



# One-Lane Roundabout

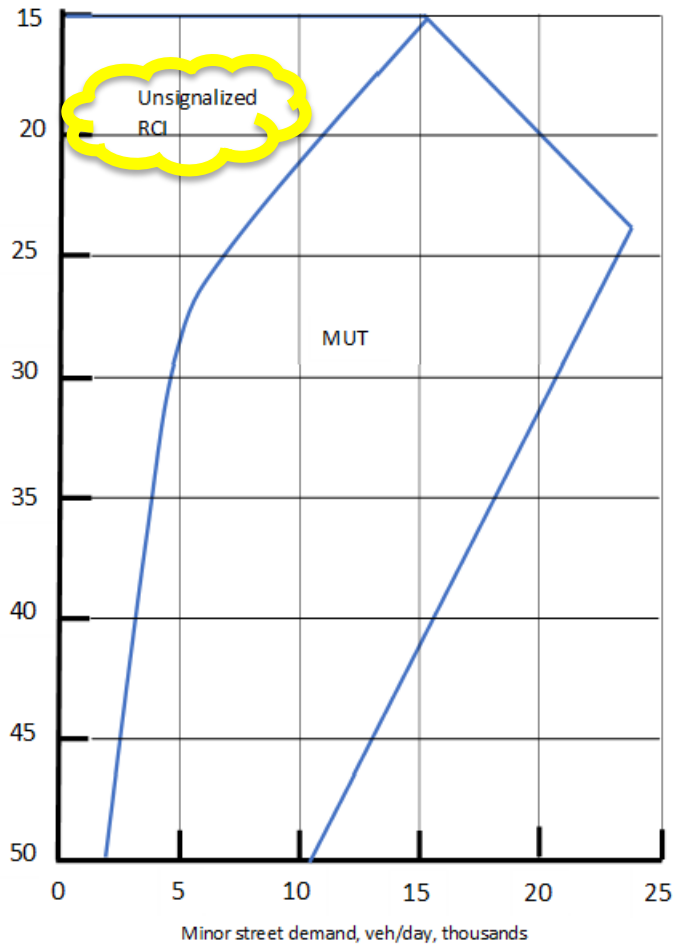
- Travel efficiency
  - Minimum delay in its niche
- Cost
  - Generally above \$2 million at NCDOT
  - Substantial construction, right-of-way, utilities
- Other impacts good
  - Trucks, peds and bikes, speeds, aesthetics

All-way stop costs 1% of full-size roundabout!

# Where Large Street Meets Small Street—Unsignalized RCI (Fig. 2)

For a four-lane major street meeting a two-lane minor street

Major street demand, veh/day, thousands

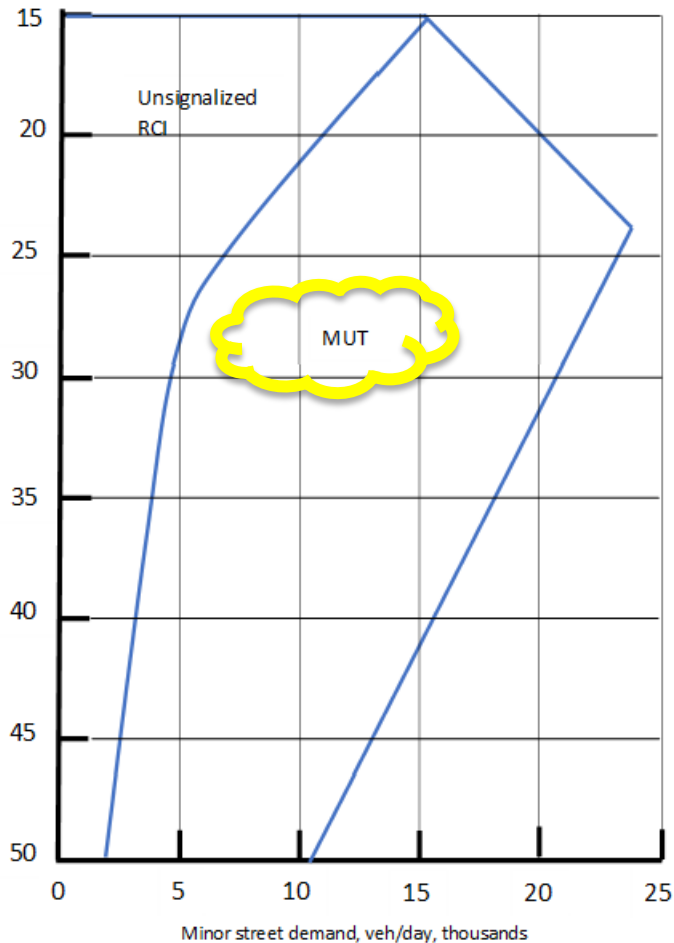


# Unsignalized RCI

- Great travel efficiency in its niche
  - Minimize minor street stopped delay
- Cost \$1-3 million
  - Need right-of-way (ROW) for bulb-outs
- Pedestrian and bicyclist good
  - Two-stage crossing
- No economic impact on retail business or residential property value

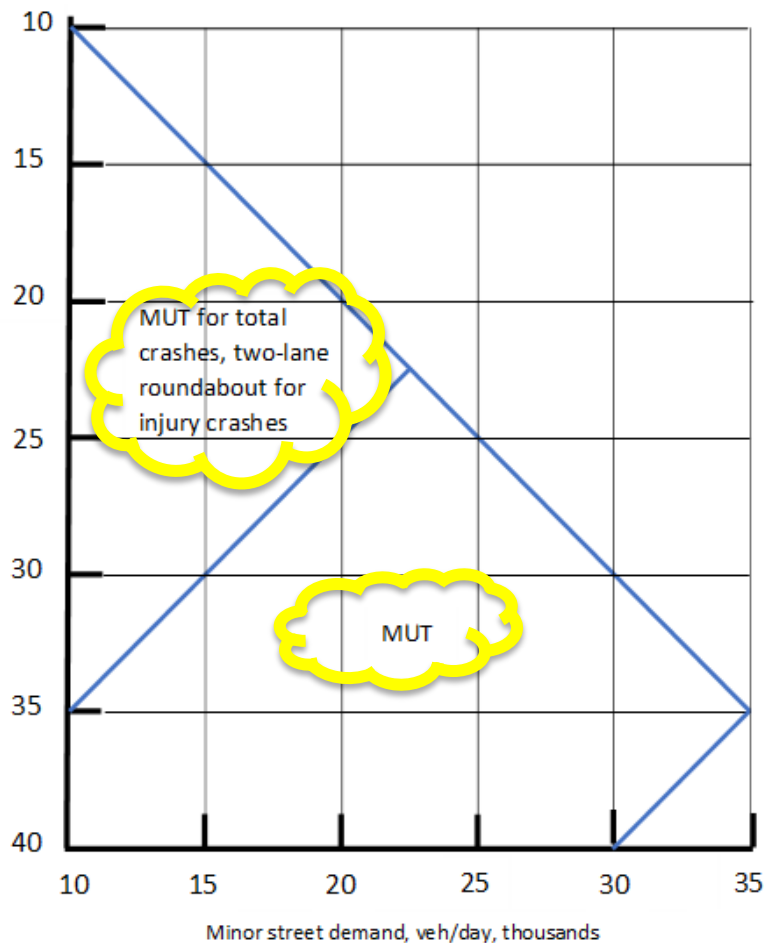
# Safest Feasible Large Intersection— Median U-Turn (Figs. 2-4)

Fig. 2 For a four-lane major street meeting a two-lane minor street  
Major street demand, veh/day, thousands

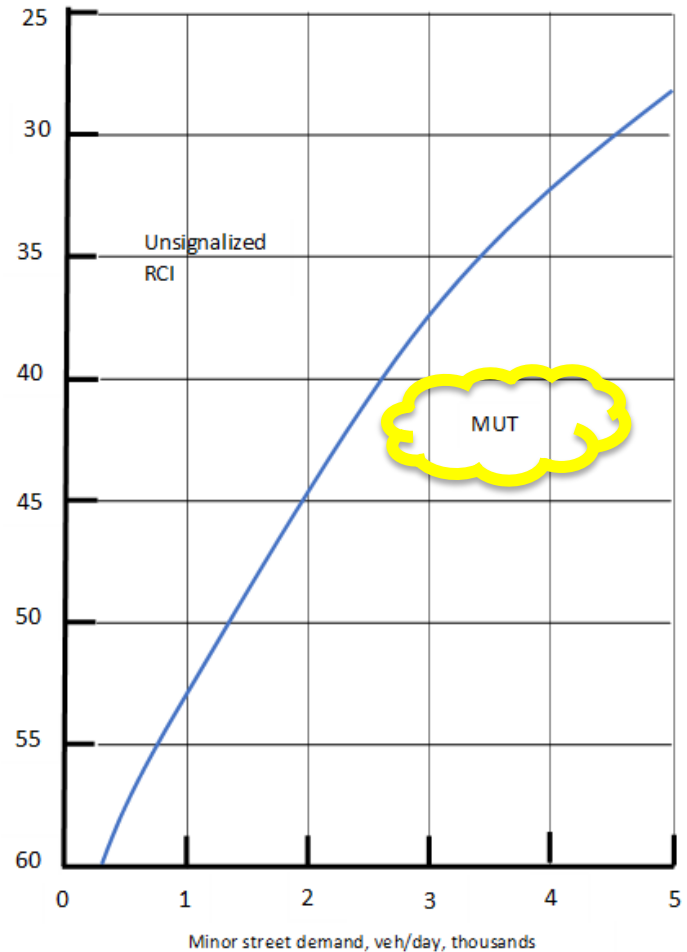


# Safest Feasible Large Intersection— Median U-Turn (Figs. 2-4)

**Fig. 3** For a four-lane major street meeting a four-lane minor street  
Major street demand, veh/day, thousands

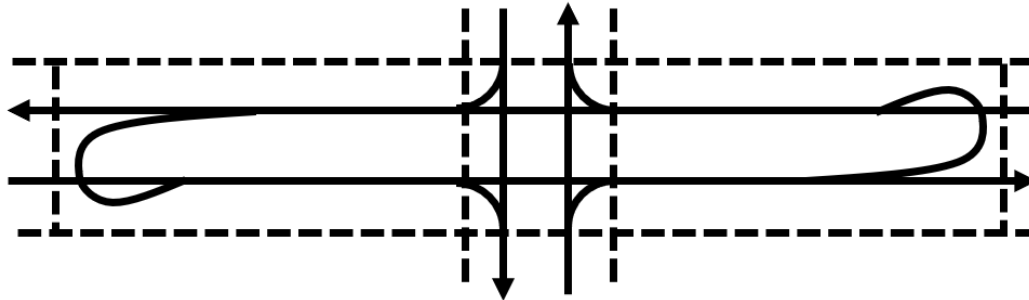


**Fig. 4** For a six-lane major street meeting a two-lane minor street  
Major street demand, veh/day, thousands



# Median U-Turn

- Good capacity with low left turn demand
  - Struggles with high left turn demand
- Cost \$5 million or more
  - Need ROW for bulb-outs
- Great for pedestrians and bicyclists
- Three open in NC, more on the way
  - Hundreds in Michigan





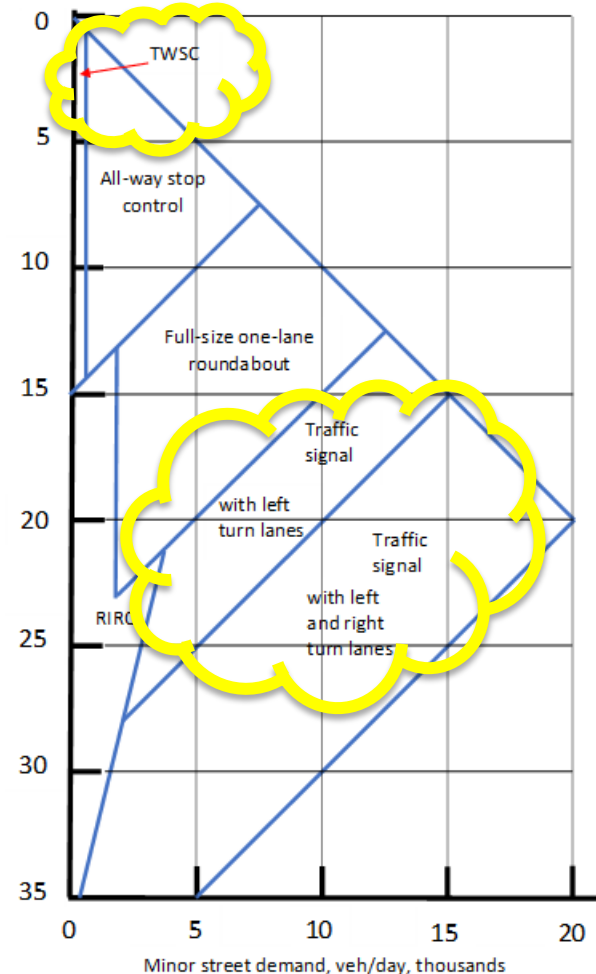
# Other Designs in Charts

- **RIRO**
  - Two-lane major and minor streets
  - When major street demand is too heavy for TWSC
- **Two-lane roundabout**
  - For injury crashes, not much total crash reduction
  - Cost above \$4 million, bicyclists a concern
  - Other impacts generally good

# Two-Way Stop or Conventional Signal Control

- Are almost never the SAFID
  - TWSC below 500 vpd on minor street
  - Signal above 25k vpd total entering, 2x2
- We all need to work to overcome mistaken public perceptions

Fig. 1 For two-lane major and minor streets  
Major street demand, veh/day, thousands



# Many Possible Reasons Not To Choose the SaFID

- The published CMF does not apply
  - Careful! No model is ever perfect
- A new design with no published CMF might be safer
- Operations
- Right of way/cost/impact
- Stakeholders
- Peds and bikes?



# POFID and BOFID

- Companion charts
- Pedestrian optimum feasible intersection design (POFID)
- Bicycle optimum feasible intersection design (BOFID)
- In each cell, feasible design that minimizes number of flags from NCHRP Report 948
- Happily, much overlap between the charts

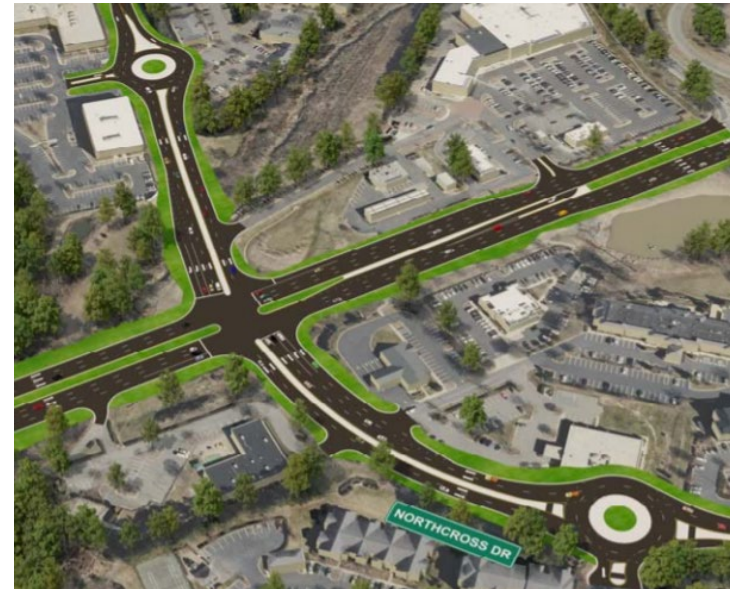
# Pedestrians--POFID

Major street			Number through lanes:	Minor street						
				2				4		6 or 8
Number through lanes	Low AADT	High AADT	Low AADT:	0	5,000	7,500	10,000	10,000	25,000 and above	Any
			High AADT:	5,000	7,500	10,000	15,000	25,000		
2	0	7,500		AWSC	AWSC	n/a	n/a	n/a	n/a	n/a
	7,500	15,000		Roundabout	Roundabout	Roundabout	Roundabout or signal	n/a	n/a	n/a
4	10,000	15,000		TWSC	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	n/a	n/a
	15,000	20,000		TWSC	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	n/a	n/a
	20,000	25,000		TWSC	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	n/a	n/a
	25,000 and above			TWSC	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	MUT	n/a
6 or 8	Any			TWSC	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	MUT	MUT

Shaded cells represent cases when a particular design minimized the weighted total number of flags for both pedestrians and bicyclists. Red lettering indicates a design that was also the safest feasible intersection design based on total crashes.

# Bowtie Intersection

- Two roundabouts
  - On minor streets 300 or more feet from main intersection
- No left turns at main intersection
  - All left turn vehicles use a roundabout
- Several in design in NC, none open yet in US
- Cost should be reasonable
  - Keeps main street narrow
- Should operate like a MUT



# Bicyclists--BOFID

Major street			Number through lanes:	Minor street						
				2			4		6 or 8	
Number through lanes	Low AADT	High AADT	Low AADT:	0	5,000	7,500	10,000	10,000	25,000 and above	Any
			High AADT:	5,000	7,500	10,000	15,000	25,000		
2	0	7,500		AWSC	AWSC	n/a	n/a	n/a	n/a	n/a
	7,500	15,000		Roundabout	Roundabout	Roundabout	Roundabout or signal	n/a	n/a	n/a
4	10,000	15,000		Unsignalized RCI or TWSC	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	Signalized RCI	n/a	n/a
	15,000	20,000		Unsignalized RCI or TWSC	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	Signalized RCI	n/a	n/a
	20,000	25,000		Unsignalized RCI or TWSC	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	Signalized RCI	n/a	n/a
	25,000 and above			Unsignalized RCI or TWSC	Bowtie or MUT	Bowtie or MUT	Bowtie or MUT	Signalized RCI	MUT	n/a
6 or 8	Any			Unsignalized RCI or TWSC	Signalized RCI	Signalized RCI	Signalized RCI	Signalized RCI	MUT	MUT

Shaded cells represent cases when a particular design minimized the weighted total number of flags for both pedestrians and bicyclists. Red lettering indicates a design that was also the safest feasible intersection design based on total crashes.

# Conclusion

- Thanks to years of safety research, SAFID charts are now available
  - Good CMFs for many intersections
- The SAFID should be the default choice
  - Burden of proof should be on proponent of less-safe design
  - If SaFID is infeasible, use second-safest design
- All-way stop, one-lane roundabout, unsig. RCI, and median u-turn dominate
- Charts for pedestrians and bicyclists



# Updated “Selecting” Document

- “Selecting Optimum Intersection and Interchange” guidance document
  - Approved by Congestion Management
  - On NCDOT website
  - Updated with new SAFID charts
  - New material on dynamic left turn intersection, three-phase intersections, treatments for high-volume undivided four-lane roads, and others

# Next Steps

- Three-leg intersection CMFs and SAFID (underway)
- How many all-way stop intersections will motorists tolerate (underway)
- Validation of NCHRP 948 ped and bike method against crash data (underway)
- CMF for 2x1 roundabout (starting soon)
- CMFs for more intersections
  - Thru-cut, quadrant, partial designs
- CMF validity near edges

# Thank You! Let's Go Fix Some Traffic

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