The 2005 NCSITE Change Plus Clearance Interval Task Force

David L. Jones, PE

Steven M. Click, PE, PhD
Tennessee Tech University

Introduction: The ITE Formula

- ITE Change Plus Clearance Interval Formula:

$$t + \frac{v}{2a + 2Gg} + \frac{w + l}{v}$$

  - t = Perception/Reaction Time (sec
  - v = Approach Speed (ft/sec)
  - a = Deceleration Rate (ft/sec^2)
  - G = Acceleration Due to Gravity (32.2 ft/sec^2)
  - g = Grade (ft/ft)
  - w = Width of Intersection (ft)
  - l = Length of Vehicle (ft)

Introduction: The ITE Formula

- Separating the Change from the Clearance calculation gives…
  - Yellow Change Interval: "prepare the driver for change"

$$t + \frac{v}{2a + 2Gg}$$

  - Red Clearance Interval: "clear the vehicle"

$$\frac{w + l}{v}$$

Issues with the ITE Formula

- ITE is not a governing body
  - There is no requirement to use the ITE formula
  - There is no national consistency with regards to how the formula is applied
  - ITE has been unsuccessful in improving compliance with the strict application
- The MUTCD does not require an All Red interval
- So what's all the fuss about? → Liability!

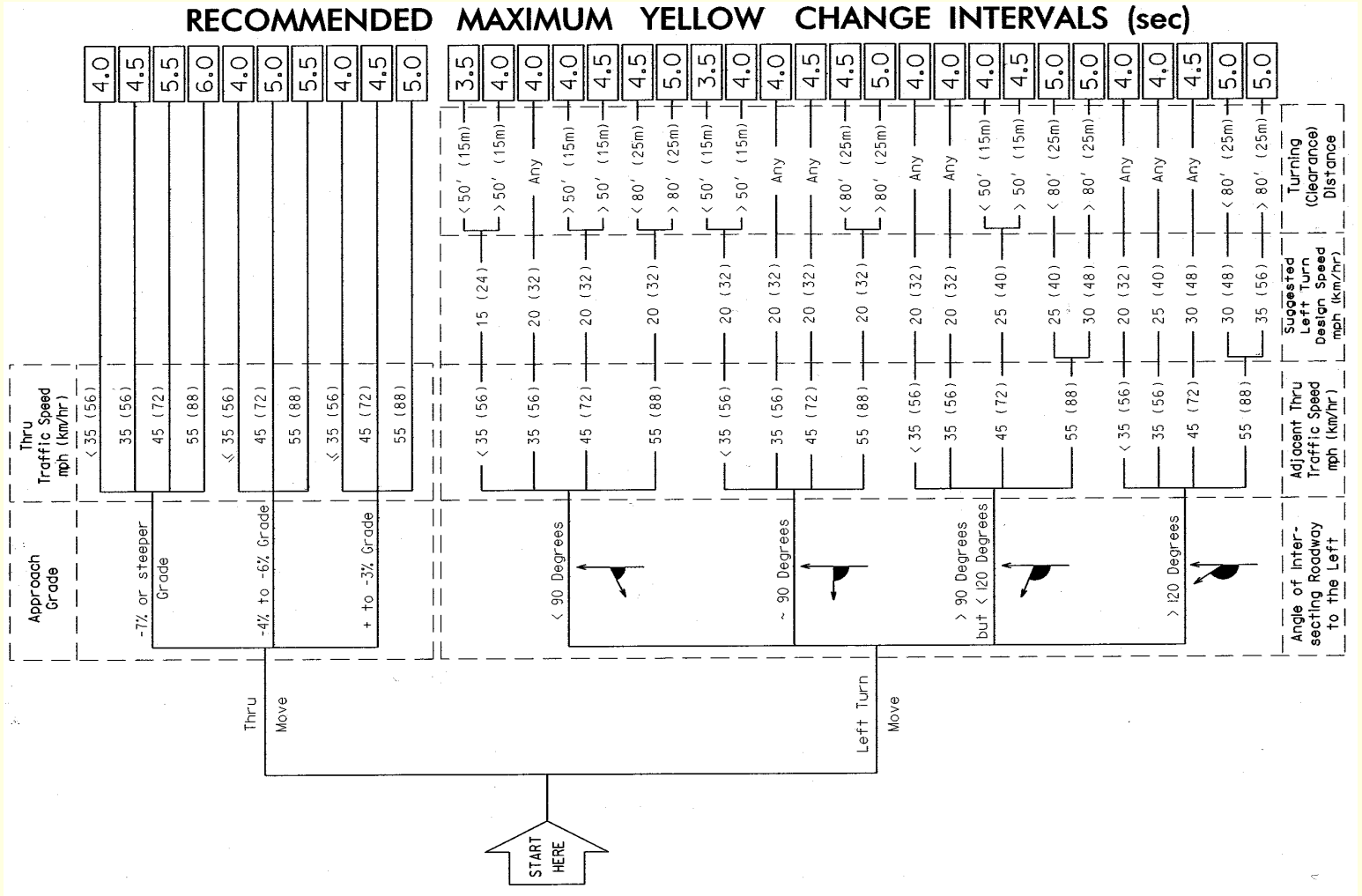
History of Practice in NC

- February 1990 Meeting on Clearance Intervals
  - Representatives from Charlotte, Durham, Greensboro, High Point, Winston-Salem, and NCDOT attend
  - NCDOT will use Strict ITE when $3 \leq Y \leq 5$
    - Time is shifted from/to All Red to keep $3 \leq Y \leq 5$
  - NCDOT will use 20 mph for left turn movement

History of NCDOT Practice

- December 1995 (1st Edition Design Manual)
  - Continue to use posted speed for through move
    - Left turn speed now varies from 15 to 35
  - Continue to apply maximum Yellows
    - Max Yellow now varies from 3.5 to 5.0
    - Max for through is based on grade and speed
    - Max for left is based on angle of turn, adjacent through speed, and total left turn clearance distance

1995 NCDOT Max Yellow Chart



History of NCDOT Practice

- October 1999 (2nd Edition Design Manual)
  - Continue to use ITE formula for Total Clearance
  - Replace Max Yellows with Standard Yellows
    - 40 mph or less, Y=4.0
    - 45-50 mph, Y=4.7
    - 55 mph, Y=5.1
  - All Red = Total Clear - Standard Yellow
    - All Red is now rounded up to nearest 0.5 second

History of NCDOT Practice

- October 1999 (2nd Edition Design Manual)
  - Regarding reason for change to Y and AR
    - Based on recollections of employees of that time
    - Most likely to reduce number of revisions during review process for PE seal
    - Eliminated problems with slightly different measurements giving 0.1 second differences in clearance times
  - Regarding Yellow time
    - New Standard Yellows ≥ Previous Maximum Yellows

History of NCDOT Practice

- March 2002 (2nd Edition Design Manual, Rev)
  - Change to use “Design Speed” for through
    - Design Speed = Speed Limit or 85th Percentile Speed
  - Change to use Standard Minimum Yellows
    - Now use first two terms of ITE to calculate Yellow
    - Compare to prior Standard Yellows based on Speed
    - Use larger of calculated and prior standard
  - Change to use All Red = Total Clear - Yellow
    - All Red is still rounded up to nearest 0.5 second

History of NCDOT Practice

- March 2002 (2nd Edition Design Manual, Rev)
  - Regarding reason for change to Y and AR
    - Based on issues related to red light cameras
    - Want to ensure we are providing drivers appropriate Yellow time before a ticket would be issued
  - Regarding Yellow time
    - Typically, Minimum Yellow (based on prior standard) will control unless grade is steeper than -2%

History of NCDOT Practice

- **July 2004** (3rd Edition Design Manual)
  - Change to Strict ITE for calculating Y and AR
    - Yellow based on first two terms of ITE equation
    - All Red based on last term of ITE equation
  - Revised reaction and deceleration from MUTCD
    - Perception/reaction time = 1.5 sec (instead of 1.0 sec)
    - Deceleration rate = 11.2 ft/sec^2 (instead of 10.0 ft/sec^2)

History of NCDOT Practice

- July 2004 (3rd Edition Design Manual)
  - Objectives for this move:
    - Desire to improve safety for left turning vehicles
    - Desire to reduce driver frustration
    - Desire to reduce red light running
    - Desire to advance national consistency

History of NCDOT Practice

- July 2004 (3rd Edition Design Manual)
  - Regarding Yellow and All Red times
    - For through movements, change to Strict ITE results in negligible differences (~0.2 sec or less)
    - For left turns…
      - Yellow typically drops from 4.0 to 3.0 (equipment based min)
      - All Red therefore typically increases by 1.0
  - Regarding new MUTCD perception/reaction time and deceleration rates
    - Very little effect

History of NCDOT Practice

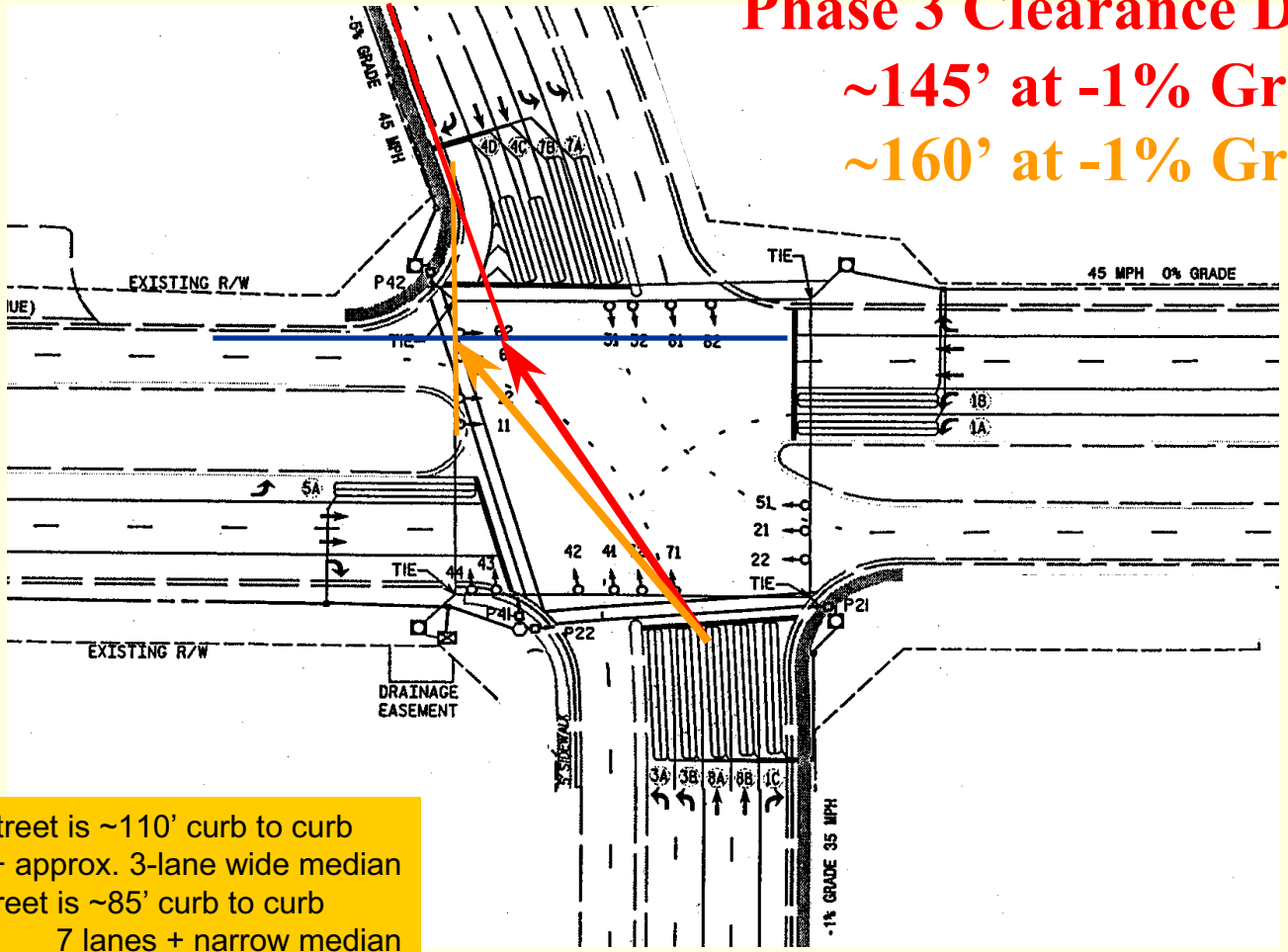
- July 2004 (3rd Edition Design Manual)
  - Regarding the concerns that arose
    - Concerns arose related to the left turn clearance times
      - Is a 3.0 second Yellow really OK?
      - Should All Red ever be longer than Yellow?
      - Are clearance times getting too long?
      - How will this affect red light running cameras?
      - And more…

History of NCDOT Practice

- December 2004 (3rd Edition Design Man, Rev)
  - Change to a Global Minimum Yellow
    - Yellow based on first two terms of ITE equation, but never < 3.5 sec
    - All Red = Total Clear - Yellow (same as last term unless Y < 3.5)
  - Intended as a temporary practice to allow for an NCSITE Task Force to review Clearance Interval Calculation in NC

Example: Phase 3 Clearance

Phase 3 Clearance Distance
~145’ at -1% Grade
~160’ at -1% Grade



The main street is ~110’ curb to curb
6 lanes + approx. 3-lane wide median
The side street is ~85’ curb to curb
7 lanes + narrow median

Clearance Intervals for example

Left Turn Design Speed = 20 mph

NCDOT Method	Phase 3 Clearance 145' at -1% Grade			Phase 3 Clearance 160' at -1% Grade			Phase 7 Clearance 150' at -5% Grade		
	Y	AR	TC	Y	AR	TC	Y	AR	TC
1990 3 < Y < 5	3.0	5.2	8.2	3.0	5.7	8.7	3.0	5.6	8.6
1995 Max Yellows	3.0	5.2	8.2	3.0	5.7	8.7	3.0	5.6	8.6
1999 Standard Yellows	4.0	4.5	8.5	4.0	5.0	9.0	4.0	5.0	9.0
2002 Standard Minimum Yellows	4.0	4.5	8.5	4.0	5.0	9.0	4.0	5.0	9.0
July 2004 Strict ITE *	3.0	5.6	8.6	3.0	6.1	9.1	3.1	5.8	8.9
Dec 2004 Global Minimum Yellow *	3.5	5.1	8.6	3.5	5.6	9.1	3.5	5.4	8.9

* Note: These calculations use the revised perception/reaction time and deceleration rate

Example: What Went "Wrong"?

- What about that 9.1 sec Total Clear?
- Intersections are getting wider!
  - More lanes
  - Wider turn radii
  - Separation of crosswalks
- Perhaps we should use a higher left turn speed? ("Legal" as allowed by Design Manual)

Clearance Intervals example

Comparison of Different Left Turn Speeds

NCDOT Method	160' at -1% Grade 20 mph			160' at -1% Grade 25 mph			160' at -1% Grade 30 mph		
	Y	AR	TC	Y	AR	TC	Y	AR	TC
1990 3 < Y < 5	3.0	5.7	8.7	3.0	4.8	7.8	3.3	4.1	7.4
1995 Max Yellows	3.0	5.7	8.7	3.0	4.8	7.8	3.3	4.1	7.4
1999 Standard Yellows	4.0	5.0	9.0	4.0	4.0	8.0	4.0	3.5	7.5
2002 Standard Minimum Yellows	4.0	5.0	9.0	4.0	4.0	8.0	4.0	3.5	7.5
July 2004 Strict ITE *	3.0	6.1	9.1	3.2	4.9	8.1	3.6	4.1	7.7
Dec 2004 Global Minimum Yellow *	3.5	5.6	9.1	3.5	4.6	8.1	3.6	4.1	7.7

* Note: These calculations use the revised perception/reaction time and deceleration rate

Summary of Practice

- NCDOT has used 6 different methods to calculate clearance intervals since 1990
  - The ITE formula is an integral part of each method
  - Total Clearance is similar in all the methods
- Regardless of method, sound engineering judgement is needed for proper application
- 2004 experience demonstrates need for re-examination of practice.

Why a Task Force?

- The Dream…
  - A multi-agency, consensus-based, consistent statewide practice for determining clearance intervals which, when applied using sound engineering judgement, properly balances safety and efficiency at the intersection
- Use NCSITE to achieve this end!
- Precedent: 2003 Late Night Flash Committee

The Task Force is Born!

- Co-Chaired by Greg Fuller and yours truly
- Roughly 1/3 DOT, 1/3 Munis, 1/3 PEF
- July 1, 2005 – Deadline for recommendation
- Early decisions
  - This process should be independent of automated red light enforcement issue
  - The ITE is a sound basis for the new recommended policy
  - One recommendation statewide (for any %HV, region, movement)

Task Force Process

- Four Subcommittees
  - General Issues – Bo Winstead:
    Design veh, clear distance, start-up time
  - Speed Issues - Pam Alexander
  - Interval Constraints – Richard Mullinax: Min/max, Y&R split, purpose and understanding of Y&R
  - Num. Input to Formulas – Melissa Cooney:
    Grade, P/R, decel
- Four meetings of entire group
- Numerous subcommittee meetings and telecoms

Task Force Data Collection

- Three areas merited data collection:
  - Left Turn Speed
    - Potential big reduction?
  - Time to Conflict Point
    - Effect unknown
  - Left Turn Clearance Measurement
    - Small + effect, but worth investigating?

Task Force Data Collection

Left Turn Speed

Site	Left Turn Angle	Single or Dual	Collection Method*	Sample Size	Speed					
					Min	15%	Avg	StDev	85%	Max
1	125	Dual	All	39	14	15.0	**18.9**	**3.4**	21.3	30
2	110	Single	All	40	11	12.0	**15.6**	**2.7**	18.0	24
3	120	Single	All	71	12	16.0	**18.4**	**2.9**	21.0	26
4	110	Single	Sample	120	14	16.0	**18.1**	**2.1**	20.0	23
5	100	Single	Sample	120	9	11.0	**13.6**	**2.2**	16.0	20
6	100	Dual	End Car	80	14	17.0	**19.0**	**1.8**	21.0	23
7	70	Dual	End Car	160	10	13.0	**14.6**	**1.6**	16.0	20
8	115	Dual	End Car	80	13	16.0	**18.7**	**2.3**	21.0	26
9	130	Dual	End Car	156	14	17.0	**19.3**	**2.3**	22.0	25
10	85	Single	End Car	160	12	15.0	**17.2**	**2.0**	19.0	23
11	90	Dual	End Car	80	13	16.0	**17.4**	**1.8**	19.2	21
ALL	-	-	-	**1106**	**9**	**14.0**	**17.1**	**2.9**	**20.0**	**30**

* **Collection Methods:**

All = Speed recorded for all vehicles making the left turn

Sample = Speed recorded for an initial vehicle, a mid-queue vehicle, and a end-of-green vehicle

End Car = Speed recorded for the last vehicle using the phase each cycle

Task Force Data Collection

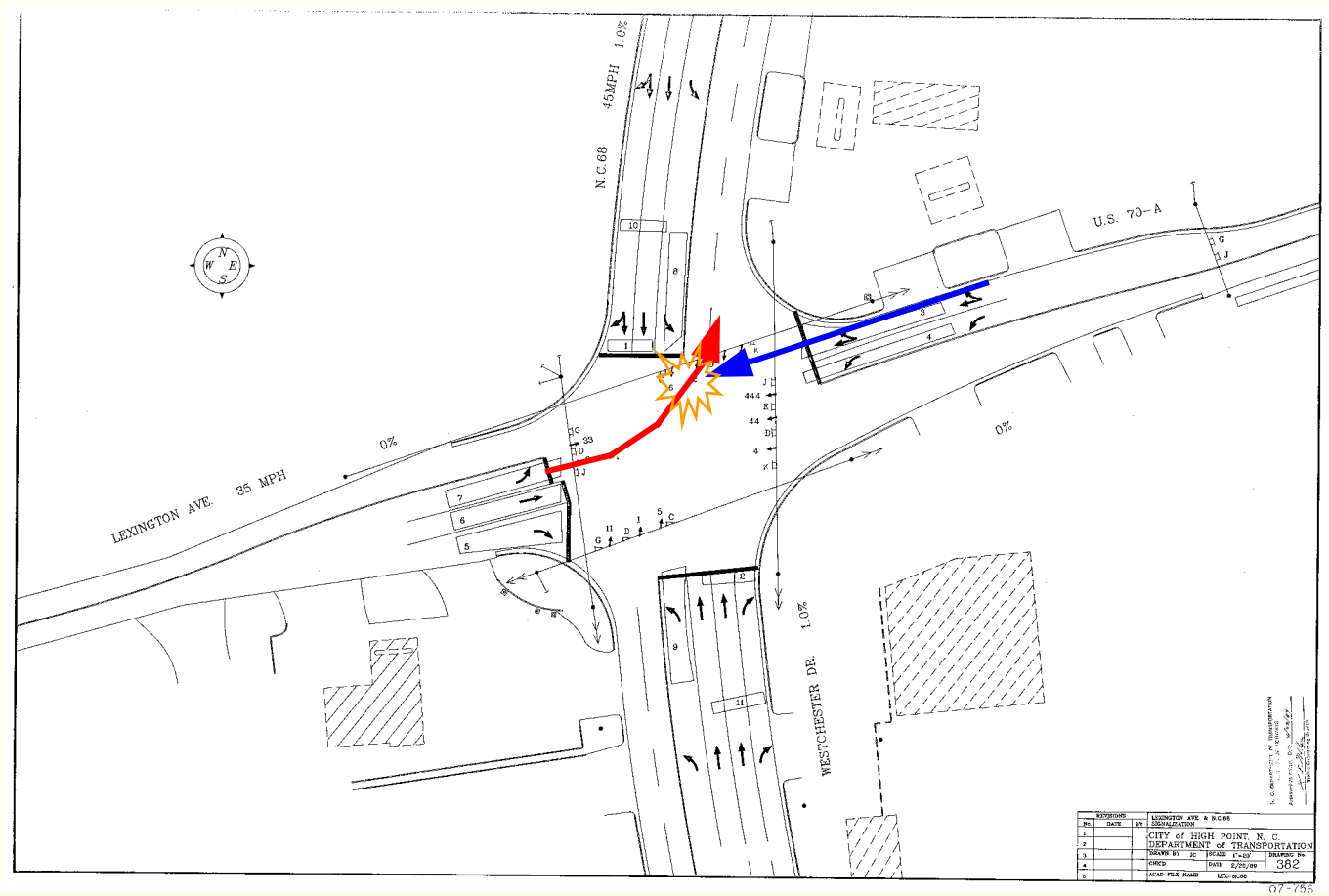
- Left Turn Speed
  - Also looked at triple lefts
  - Results:

    Observed speeds were <u>less</u> than DOT speed assumption!!!

  - Discarded due to negative to neutral effect

Task Force Data Collection

- Time to Conflict Point



Task Force Data Collection

- Time to Conflict Point
  - Results:

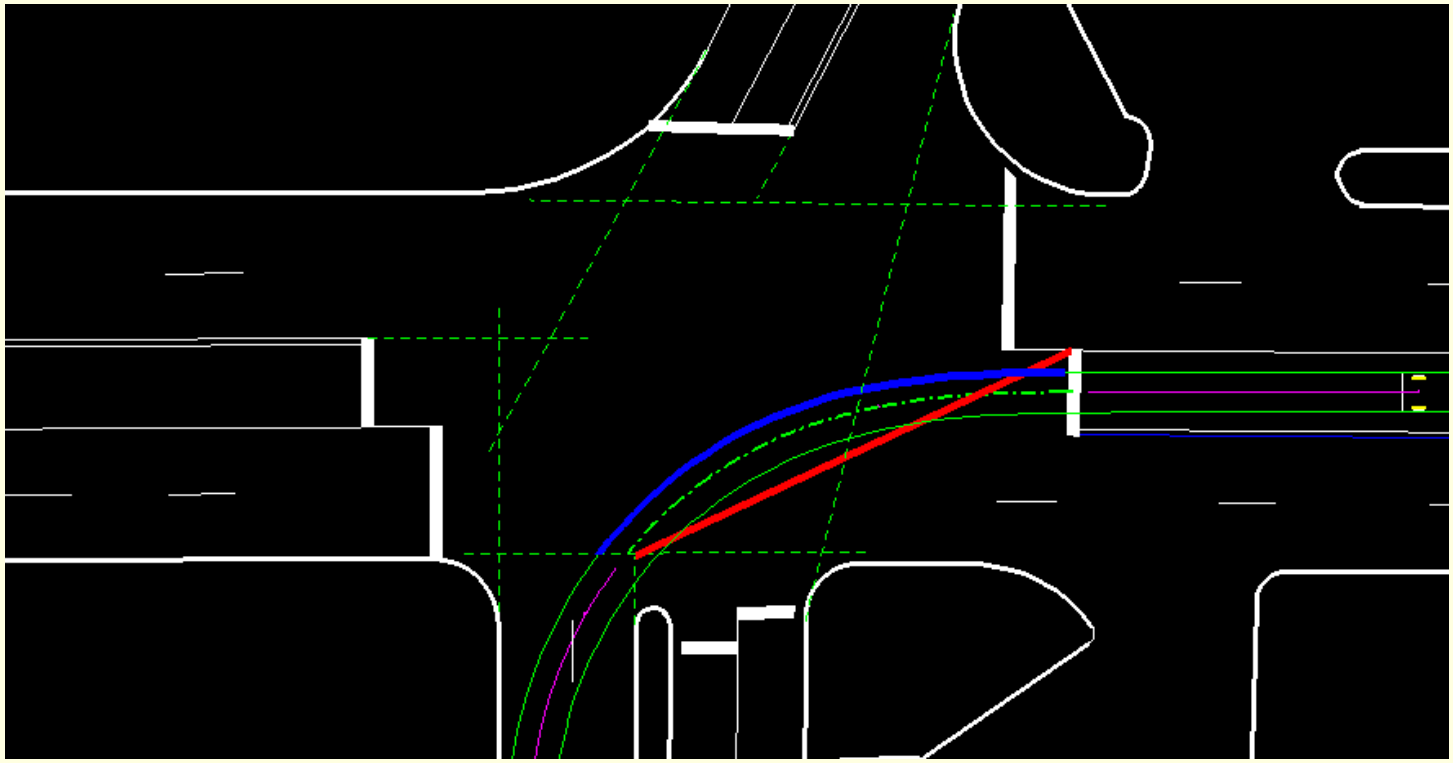
	Vehicle Opposing Left Turn	
	Is Stopped	Is Moving
Average Time to Conflict Point:	4.33 sec	0.97 sec
85th Percentile Time to Conflict Point:	3.48 sec	0.81 sec

Note: N=67 for each move

  - Promising, but discarded after literature review

Task Force Data Collection

- Left Turn Clearance Distance



Red = Existing method Blue = Alternate method

Task Force Data Collection

- Left Turn Clearance Distance
  - Results:

    Left turn clearance distance increased by average of 2.2 feet

    At 20 mph, this increases red time by only .075 sec

  - Discarded due to minimal and negative effect

Task Force Recommendation

- Yellow
  - Speed (v) retained
  - P/R (t) and decel (a) retained
  - Factor in positive grade
  - Y > 6 sec prompts “Stakeholder Discussion”
  - No “shifting” of time from AR to Y
  - Should result in better consistency; no arbitrary shifting of time or arbitrary values

(New policies in RED)

Task Force Recommendation

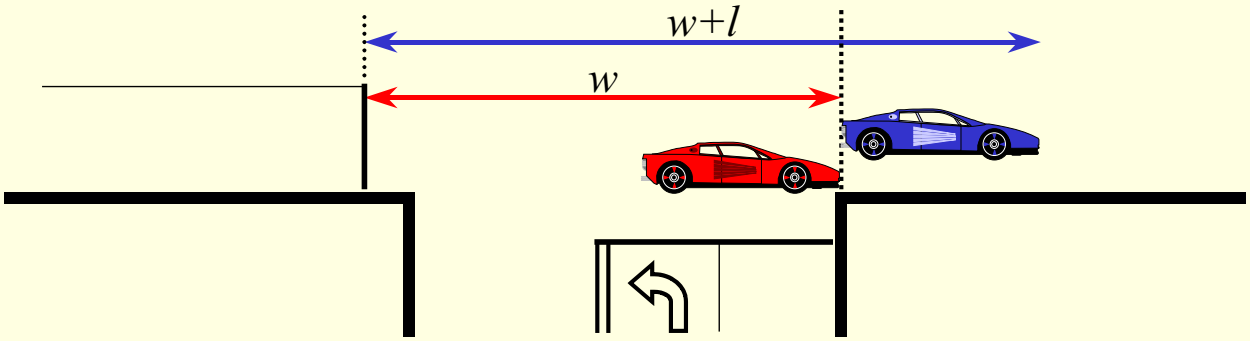
- All Red
  - Minimum value of 1 sec
  - W is taken to far side of RT lane
  - In the presence of a crosswalk with pedestrian signals, the clearance distance be taken to the near side of the crosswalk
  - That a crosswalk without pedestrian signals would not be considered when determining clearance distance

Task Force Recommendation

- All Red
  - Remove “L” from equation
  - Net effect:

    - 0.68 sec @ 20 mph

$$AR = \frac{w}{v}$$



Task Force Recommendation

- All Red - Next, if the initial calculation results in an All Red time greater than 3.0 seconds, the red time be recalculated as follows

$$AR = \frac{1}{2}\left(\frac{w}{v} - 3\right) + 3$$

  - AR > 4 sec prompts “Stakeholder Discussion”

Task Force Recommendation

- Red - Rationale
  - The procedure gives equal weight to safety concerns caused by long red times and safety concerns caused by short red times.
  - The procedure offers a smooth transition between "nominal" and "excessive" All-Red calculations.
  - Longer clearance distances will still receive a longer All Red.
  - The method is easy to understand and apply.

Task Force Recommendation

- Red – Typical calculations

Speed		Clearance Distance (feet)						
mph	fps	50	75	100	125	150	175	200
20	29.4	1.8	2.6	3.3	3.7	4.1	4.5+	5.0+
25	36.8	1.4	2.1	2.8	3.3	3.6	3.9	4.3
30	44.1	1.2	1.8	2.3	2.9	3.3	3.5	3.8
35	51.5	1.0	1.5	2.0	2.5	3.0	3.3	3.5
45	66.2	0.8*	1.2	1.6	1.9	2.3	2.7	3.1
55	80.9	0.7*	1.0	1.3	1.6	1.9	2.2	2.5
65	95.6	0.6*	0.8*	1.1	1.4	1.6	1.9	2.1

* Less than 1.0 second minimum, increase all red time to 1.0

\+ Greater than ~~4.5~~ 4.0 sec threshold, requires stakeholder meeting prior to approval

Conclusion

- Task Force met deadline
- Task Force received input from a broad spectrum of interests
- Task Force conducted valuable research
- Results submitted to TRB
- Recommended policy enacted in August 2005

Questions?

- David L. Jones, PE
  - dljones@pbsj.com
  - 919.431.5249
- Steven M. Click, PE, PhD
  - sclick@tntech.edu
  - 931.372.6464