Stop Sign-Controlled Intersections:

Enhanced Signs and Markings

A Winston-Salem Success Story

This case study is one in a series documenting successful intersection safety treatments and the crash reductions that were experienced. Traffic engineers and other transportation professionals can use the information contained in the case study to answer the following questions:

- What are some inexpensive treatment options to consider that can reduce crashes at stop sign-controlled intersections?
- How many crashes did the treatments reduce?
- Are there any implementation issues associated with these treatments, and if so, how can they be overcome?

U.S. Department of Transportation
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Introduction

One-third of all intersection crashes in the United States, and more than 40 percent of fatal crashes, occur at stop sign-controlled intersections[1]. A major problem is failure to see the stop sign and/or to know where to stop. Past research has shown that simple, low-cost treatment enhancements such as increasing the visibility of stop signs, and/or adding pavement markings, can improve driver compliance with the stop sign and reduce the number and severity of crashes[2].

Objective

The following case study showcases four successful and effective low-cost strategies that measurably improved safety at stop sign-controlled intersections in Winston-Salem, NC. The treatments included adding larger and additional stop signs, "Stop Ahead" advance traffic control signs, and enhanced pavement markings.

"The benefits to the city are clear. By taking an active role in roadway safety, and using simple low-cost traffic engineering solutions, Winston-Salem has created a much safer driving environment for motorists. These improvements will continue to yield positive results as the city population grows and average daily traffic (ADT) continues to rise."

Stanley F. Polanis
Director of Transportation
City of Winston-Salem, NC

Treatment Summary

All intersection examples used in this report are from Winston-Salem, NC. Existing intersection treatments met minimum Manual on Uniform Traffic Control Devices (MUTCD) standards. This case study examines the application of four successful combinations of intersection treatment enhancements that reduced crashes at stop sign-controlled intersections:

1) Larger (30-inch) stop signs with "Stop Ahead" advance traffic control sign and added pavement markings (double-yellow centerline and stop bars) to help delineate traffic at the intersection
2) Added pavement markings (double-yellow centerline and stop bars) to existing (24-inch) stop signs
3) Additional and larger (30-inch) stop signs
4) Additional and larger (30-inch) stop signs and added pavement markings (double-yellow centerline and stop bars).

(Note: Complete tables for each set of enhanced treatments appear at the end of this document.)

Evaluation Methodology

This case study examines 16 stop sign-controlled intersections in Winston-Salem, NC, with a high incidence of crashes (many with injuries) due to driver violation of the stop-control condition.* Crash reduction results were based on a review of "before and after" data from these intersections during a minimum of three years, between 1988—2002.** (The "before" and "after" observation periods ranged between 39-55 months depending on the intersection).

Results

1. Larger (30-inch) stop signs with "Stop Ahead" advance traffic control sign and added pavement markings

Problem: Drivers were violating stop-controls in four Winston-Salem stop sign-controlled intersections due to poor visibility of the signs and markings, leading to higher numbers of crashes at these intersections.

Solution: The city sought to reduce crashes by improving visibility of the stop-controls through enhanced low-cost signs and markings that were easy to implement. The posted speed limit on all the approaches was 35 mph except for the intersection of Buena Vista Road and Oaklawn Avenue which was 25 mph. The updated countermeasures included:

- Replaced the existing 24-inch stop signs with larger 30-inch signs (the MUTCD specifies 24-inch as the minimum size).
- Placed stop bars, consisting of a solid 12-inch white line extending across the approach lanes, to indicate the point behind which vehicles are required to stop, in compliance with a stop sign.
- Placed a short segment of double-yellow centerlines (the two-directional no-passing zone markings, up to 50 feet in length) prohibiting crossing the centerline markings for passing in either direction.
- Installed "Stop Ahead" advance traffic control signs (30-inch) on the approaches for two of the intersections (Cameron and Ivy Streets).

These relatively inexpensive treatments have proven effective in mitigating crashes and enhancing safety. **The city experienced an average crash reduction of 56.9 percent per year at these intersections.** "Stop Ahead" signs, although not independently evaluated, seem to have contributed to the crash reductions. See Appendix A for a more detailed tabular summary of these treatments.

Treatment	Location	Reduction in Crashes Per Year
• 30-inch stop signs (replaced 24-inch signs) • "Stop Ahead" advance traffic control sign • Double-yellow centerline and stop bars	Twelfth Street & Cameron Avenue (Stop sign on Cameron Avenue)	**75%**
• 30-inch stop signs (replaced 24-inch signs) • "Stop Ahead" advance traffic control sign • Double-yellow centerline and stop bars	Thirtieth Street & Ivy Avenue (Stop sign on Ivy Avenue)	**90.7%**
• 30-inch stop signs (replaced 24-inch signs) • Double-yellow centerline and stop bars	Buena Vista Road & Oaklawn Avenue (All-way stop)	**74.6%**
• 30-inch stop signs (replaced 24-inch signs) • Double-yellow centerline and stop bars	Twentieth Street & Thurmond Street (Stop sign on 20th Street)	**6.7%**
Average		**56.9%**

Table 1: Larger (30-inch) stop signs with "Stop Ahead" advance traffic control sign and added pavement markings (treatment data and results)

2. Added pavement markings (double-yellow centerline and stop bars) to existing (24-inch) stop signs

Problem: Four two-way, two-lane stop sign-controlled intersections of minor arterial roads with a posted speed limit of 35 mph or less were experiencing a high number of crashes. Stop signs were in place, visible and in good condition. However, there were no pavement markings on the approaches.

** These intersections did not experience a significant number of fatalities.*

***Note that crash reduction averages in this report reflect the percent reduction per year based on the difference between the total number of "before" and "after" crashes. Injury reductions per year are noted where supporting data was available.*

Solution: The city sought to reduce crashes by clarifying the proper stopping position for vehicles through enhanced pavement markings that were easy to implement. The updated countermeasures included:

- Placing a short interval of double-yellow centerlines (up to 50-feet).
- Placing stop bars (12-inches wide).

These pavement marking treatments were designed to make the intersection and proper stop position more conspicuous to drivers, and thereby increase the driver alertness to the intersection control. These simple, low-cost countermeasure enhancements significantly reduced injury and overall crashes, as shown in the table to the right. **These countermeasures resulted in an average crash reduction of 52.7 percent and reduced injuries by 70 percent per year.** See Appendix A for a more detailed tabular summary of these treatments.

3. Additional and larger (30-inch) stop signs

Problem: Four two-way, two-lane stop sign-controlled intersections of minor arterial roads with a posted speed limit of 35 mph or less were experiencing a high number of crashes. The causes of these crashes could not be readily determined from the crash reports—i.e., it was not clear whether motorists were running the stop signs or stopping but then pulling into the path of an oncoming vehicle.

Solution: The city decided to visually emphasize the required stop by:

- Placing an additional stop sign on the left side of the stop approach roadway.
- Using larger (30-inch) stop signs for the intersection.

These countermeasure enhancements were aimed to better alert drivers and thus enhance their ability to safely navigate through the intersection. **At these locations the city experienced an average crash reduction of 48.3 percent per year.** See Appendix A for a more detailed tabular summary of these treatments.

4. Additional and larger (30-inch) stop signs with added pavement markings

Problem: Four two-way, two-lane stop sign-controlled intersections of minor arterial roads with a posted speed limit of 45 mph or less were experiencing a high number of crashes. While existing stop signs were in place, drivers did not always have an adequate view of approaching traffic from the cross-streets.

Solution: The city decided to implement a set of low-cost signs and markings countermeasure enhancements to heighten the awareness of the intersection control and

Double-yellow centerline and stop bars added to existing (24-inch) stop sign.

Treatment	Location	Reduction in Crashes Per Year
Double-yellow centerline and stop bars	Second Street and Spring Street (Stop sign on Spring Street)	**51.4%**
Double-yellow centerline and stop bars	Cameron Avenue and Mt. Zion Place (Stop sign on Mt. Zion Place)	**83.3%**
Double-yellow centerline and stop bars	Thirtieth Street & Bon Air Avenue (Stop sign on Bon Air Avenue)	**40%**
Double-yellow centerline and stop bars	Brindle Street and Sprague Street/Willard Road (Stop sign on Brindle Street)	**41.7%**
Average		**52.7%**

Table 2: Added pavement markings (double-yellow centerline and stop bars) to existing (24-inch) stop signs (treatment data and results)

Treatment	Location	Reduction in Crashes Per Year
Dual 30-inch stop signs	Reynolds Road & West End Blvd (Stop sign on West End Blvd)	**71.4%**
Dual 30-inch stop signs	Broad Street & Brookstown Avenue (Stop sign on Brookstown Avenue)	**33.8%**
Dual 30-inch stop signs	Third Street & Cameron Avenue (Stop sign on Cameron Avenue)	**80%**
Dual 30-inch stop signs	Sixteenth Street & Ivy Avenue (Stop sign on 16th Street)	**28.6%**
Average		**48.3%**

Table 3: Additional and larger (30-inch) stop signs (treatment data and results)

Additional (left and right side of street) and larger (30-inch) stop signs with stop bars.

encourage drivers to stop in a position that provided an effective view of approaching traffic. The improved countermeasures included:

- Placing an additional stop sign on the left side of the stop approach roadway and use of larger (30-inch) stop signs for the intersection at all stop sign-controlled approaches.
- Placing 12-inch stop bars at all stop sign-controlled approaches.
- Installation of short segments of double-yellow centerlines (up to 50-feet) at two of the approaches (Cherry Street and Greenwich Road).

At these locations the city experienced an average crash reduction of 65.9 percent with injuries down by 65 percent per year as well. See Appendix A for a more detailed tabular summary of these treatments.

Discussion

Implementation Issues

Winston-Salem experienced no implementation issues with these countermeasures.

Cost

The costs for implementing the countermeasure enhancements were low: Approximately $350 for a 30-inch stop sign or a "Stop Ahead" advance warning sign, and approximately $1,250 for the enhanced pavement markings (centerlines and stop bars).

Time Frame

The signing and pavement marking treatments were implemented within 3 months.

Effectiveness

The combinations of enhanced treatments discussed have been effective in reducing crashes at these stop sign-controlled intersections. The city attributes its success to targeting appropriate intersection approaches that would benefit from enhanced treatments—specifically, intersections where conditions allow an approaching driver to see the enhanced treatments at a distance, in time to respond. In addition, the city was committed to adequately maintain the signs and markings.

Treatment	Location	Reduction in Crashes Per Year
• Dual 30-inch stop signs • Double-yellow centerline and stop bars	Twentieth Street & Cherry Street (Stop sign on Cherry Street)	**78.6%**
• Dual 30-inch stop signs • Double-yellow centerline and stop bars	Greenwich Road & Knollwood Street/Hanover Arms Court (Stop sign on Greenwich Road)	**66.7%**
• Dual 30-inch stop signs • Stop bars	Indiana Avenue & Motor Road (Stop sign on Motor Road)	**63.6%**
• Dual 30-inch stop signs • Stop bars	Fifth Street & Lowery Court (Stop sign on Lowery Court)	**50%**
Average		**65.9%**

Table 4: Additional and larger (30-inch) stop signs with added pavement markings (treatment data and results)

Summary of Results

The "before" conditions at all 16 of these intersections met minimum MUTCD standards. The safety enhancements discussed in this case study were added to reduce crashes. The combinations of enhanced countermeasures installed in these Winston-Salem stop sign-controlled intersections reduced total crashes at these intersections by approximately 55 percent, and total injuries by an average of 70 percent per year. The average reductions in crashes achieved by the treatments are consistent with the overall crash reductions mentioned in the Desktop Reference for Crash Reduction Factors by the Department of Transportation (USDOT) Federal Highway Administration (FHWA)[8]. The findings also indicate that installing stop signs larger than the minimum size of 24-inches, as specified in the MUTCD, helps to increase driver awareness of the stopped condition.

References

1) Insurance Institute for Highway Safety, Volume 37, No 9, October 26, 2000.
2) Douglas A. Ripley. "Quantifying the Safety Benefits of Traffic Control Devices – Benefit-Cost Analysis of Traffic Sign Upgrades." Mid-Continent Transportation Research Symposium, Ames, Iowa, August 2005.
3) Briglia Jr., P.m. (1982). An evaluation of 4-way stop sign-control. ITE Journal, 52, 16-19.
4) Hauer, E., and Lovell, J. (1986). The safety affect of conversion to all-way stop-control. Transportation Research Record, vol. 1068, 103-107.
5) Gattis, J. "Supplemental Signing for Stop Signs." University of Arkansas. Fayetteville, AR. October 1995.
6) Von Houten, R., & Retting, R.A. (2001). Increasing motorist compliance and caution at stop signs. Journal of Applied Behavior Analysis, 34, 185-193.
7) Retting. R.A., Helen B. Weinstein, Mark G. Solomon. "Analysis of motor vehicle crashes at stop signs in four U.S. cities". Journal of Safety Research 34 (2003) 485-489.
8) Desktop Reference for Crash Reduction Factors, FHWA-SA-07-015, USDOT FHWA September 2007 (Pg 37, 38).
9) NCHRP Report 500. Volume 05: A Guide for Addressing Unsignalized Intersection Collisions, v-73, Transportation Research Board, Washington, D.C, 2003.

Appendix A

Treatment	Location	Implementation Date	Before				After				Percent Reduction in Crashes/Year (Injuries/Year)
			Months	Crashes	Fatalities	Injuries	Months	Crashes	Fatalities	Injuries	
1. Larger (30-inch) stop signs with "Stop Ahead" advance traffic control sign and added pavement markings											**56.9%**
• 30-inch stop signs (replaced 24-inch signs) • "Stop Ahead" advanced traffic control sign • Double-yellow centerline and stop bars	Twelfth Street and Cameron Avenue (Stop sign on Cameron Avenue)	Apr-88	52	12	0	6	52	3	0	N/A	**75% (unknown)**
• 30-inch stop signs (replaced 24-inch signs) • "Stop Ahead" advanced traffic control sign • Double-yellow centerline and stop bars	Thirtieth Street and Ivy Avenue (Stop sign on Ivy Avenue)	Apr-89	51	11	0	11	50	1	0	N/A	**90.7% (unknown)**
• 30-inch stop signs (replaced 24-inch signs) • Double-yellow centerline and stop bars	Buena Vista Road and Oaklawn Avenue (All-way stop)	Dec-87	48	7	1	12	54	2	N/A	N/A	**74.6% (unknown)**
• 30-inch stop signs (replaced 24-inch signs) • Double-yellow centerline and stop bars	Twentieth Street and Thurmond Street (Stop sign on 20th Street)	Mar-91	50	15	0	9	50	14	N/A	N/A	**6.7% (unknown)**
2. Added pavement markings (double-yellow centerline and stop bars) to existing (24-inch) stop signs											**52.7% (70%)**
Double-yellow centerline and stop bars	Second Street and Spring Street (Stop sign on Spring Street)	Nov-89	46	22	0	6	43	10	N/A	N/A	**51.4% (unknown**
Double-yellow centerline and stop bars	Cameron Avenue and Mt. Zion Place (Stop sign on Mt. Zion Place)	Apr-02	39	6	0	6	39	1	0	0	**83.3% (100%)**
Double-yellow centerline and stop bars	Thirtieth Street & Bon Air Avenue (Stop sign on Bon Air Avenue)	Jul-02	49	5	0	7	49	3	0	2	**40% (71%)**
Double-yellow centerline and stop bars	Brindle Street and Sprague Street/Willard Road (Stop sign on Brindle Street)	Jun-02	50	12	0	14	50	7	0	6	**41.7% (57%)**

Treatment	Location	Imple-mentation Date	Before				After				Percent Reduction in Crashes/Year (Injuries/Year)
			Months	Crashes	Fatalities	Injuries	Months	Crashes	Fatalities	Injuries	
3. Additional and larger (30-inch) stop signs											**48.3%**
Dual 30-inch stop signs	Reynolds Road & West End Blvd (Stop sign on West End Blvd)	Dec-88	47	14	0	5	47	4	N/A	N/A	**71.4% (unknown)**
Dual 30-inch stop signs	Broad Street & Brookstown Avenue (Stop sign on Brookstown Avenue)	Apr-93	52	37	0	13	51	24	N/A	N/A	**33.8% (unknown)**
Dual 30-inch stop signs	Third Street & Cameron Avenue (Stop sign on Cameron Avenue)	Nov-98	47	10	0	3	47	2	N/A	N/A	**80% (unknown)**
Dual 30-inch stop signs	Sixteenth Street & Ivy Avenue (Stop sign on 16th Street)	Jul-02	55	7	0	4	55	5	0	0	**28.6% (100%)**
4. Additional and larger (30-inch) stop signs with added pavement markings											**65.9% (65%)**
• Dual 30-inch stop signs • Double-yellow centerline and stop bars	Twentieth Street & Cherry Street (Stop sign on Cherry Street)	Aug-89	44	14	0	12	44	3	N/A	N/A	**78.6% (unknown)**
• Dual 30-inch stop signs • Double-yellow centerline and stop bars	Greenwich Road & Knollwood Street/Hanover Arms Court (Stop sign on Greenwich Road)	May-02	44	6	0	5	44	2	0	2	**66.7% (60%)**
• Dual 30-inch stop signs • Stop bars	Indiana Avenue & Motor Road (Stop sign on Motor Road)	Jul-02	43	11	0	7	43	4	0	2	**63.6% (71%)**
• Dual 30-inch stop sign • Stop bars	Fifth Street & Lowery Court (Stop sign on Lowery Court)	Jun-02	55	10	0	8	55	5	0	3	**50% (62%)**

For More Information

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Visit FHWA's intersection safety web site to download this and other case studies highlighting proven intersection safety treatments from across the country:

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