CITY OF URBANA, ILLINOIS
DEPARTMENT OF PUBLIC WORKS

ENGINEERING

M E M O R A N D U M

TO: **Mayor Laurel L. Prussing and Members of the City Council**

FROM: **William R. Gray, Public Works Director**
Craig E. Shonkwiler, Assistant City Engineer

DATE: **May 22, 2014**

RE: **Windsor Road Improvement Project – Race Street to Philo Road**
- **Proposed Traffic Signals at Windsor Road and Race Street Intersection**

INTRODUCTION

New traffic signals with features for pedestrians such as visual countdown timers and non-visual formats, which include audible tones and vibrotactile surfaces, are proposed to replace the existing all-way stop signs at the Windsor Road and Race Street intersection as part of the Windsor Road Improvement Project scheduled for construction in 2014-15.

Windsor Road Corridor

Windsor Road within the cities of Urbana and Champaign is a major east-west corridor on the south side of both communities. Windsor Road is functionally classified as a minor arterial, which indicates the primary designation of the street is to move higher volumes of intra-community traffic at higher speeds as compared to streets classified as collector or local streets, which move lower volumes of traffic at lower speeds and are contained mostly within residential areas.

The Windsor Road/Race Street intersection is the only remaining all-way stop controlled intersection along the seven mile Windsor Road corridor from Duncan Road in Champaign to High Cross Road in Urbana.

Capital Improvement Plan

Traffic signals at the Windsor Road/Race Street intersection have been identified as a future improvement in Urbana's Capital Improvement Plan annually since 2005.

Previous Roundabout Study

In 2011 the city undertook a feasibility study for installing a modern roundabout at this intersection. Based on public input, additional cost compared with a traditional intersection and right-of-way acquisition required, this was not recommended.

Signal Justification – MUTCD Warrant Analysis

A signal warrant analysis was performed by the city's consulting engineer, Hanson Professional Services, Inc. (Hanson), to determine if traffic signals were justified using nationally accepted guidelines contained in the Federal Highway Administration's Manual on Uniform Traffic Control Devices (MUTCD). Attachment A contains Hanson's signal warrant analysis memorandum.

For a traffic signal to be considered, it is suggested that one or more of nine signal warrants identified in the MUTCD be met. Per Attachment A, Hanson determined the Windsor Road and Race Street intersection meets Warrant 1, the Eight-Hour Vehicular Volume warrant and Warrant 2, the Four-Hour Vehicular Volume warrant. The warrant condition for Warrants 1 and 2 basically indicates the traffic volumes on Windsor Road and on Race Street are high enough to justify traffic signals at that intersection.

Crash Analysis

Hanson also analyzed Urbana Police Department and Illinois Department of Transportation crash data within the Windsor Road corridor from Race Street to Philo Road for the years 2009 through 2013. Attachment A from Hanson contains crash information and analysis at the Windsor Road and Race Street intersection.

Hanson found few injury crashes in the project corridor. Hanson did find a relatively high number of crashes occurring at the Windsor Road and Race Street intersection that they attributed to failure to yield right-of-way or improper lane usage, both of which are typically associated with the all-way stop control intersections. Hanson further stated in their memo that a "traffic signal should lower the occurrence of this type of crash."

Advantages and Disadvantages of Traffic Signals

Attachment B from the Federal Highway Administration contains detailed information on the advantages and disadvantages of traffic signals.

Options

The following are options for the Mayor and City Council to consider:

Option 1: Do Nothing – Keep All-Way Stop Control

Pros:

- No additional cost to the city;
- No annual maintenance and energy cost;
- Existing traffic levels are adequately handled.

Cons:

- Traffic does not move through the intersection in an orderly manner;
- The capacity of the intersection is not increased. Increased traffic backups can be expected as traffic along the Windsor Road corridor grows;
- Current failure to yield right-of-way and improper lane usage crashes are not addressed;
- Crossing of the intersection by pedestrians and the disabled is not enhanced;

- Opportunity to signalize intersection with the Windsor Road Improvement Project is lost.

Option 2: Install Traffic Signals

Pros:

- Allocate right-of-way or "green" time based on traffic demand;
- More orderly movement of traffic through the intersection;
- Reduce certain types of accidents;
- Consistent and predictable with intersection control along the corridor;
- The intersection will be able to handle future traffic volumes associated with growth along the corridor;
- Failure to yield right-of-way and improper lane usage crashes are expected to be reduced;
- Crossing of the intersection safely by pedestrians and the disabled is enhanced;
- Intersection is signalized with the Windsor Road Improvement Project.

Cons:

- Signalization of the intersection is expected to cost $205,000;
- Annual energy cost is expected to be $1,000 per year;
- Increases in the frequency of rear-end crashes can be expected;
- May lead motorists to use other routes;

FISCAL IMPACTS

The design engineering costs are contained within the costs associated with the design of the Windsor Road Improvement Project. The estimated cost to construct the traffic signals with the Windsor Road Improvement Project is approximately $205,000 and will be funded solely with Local Motor Fuel Tax funds via the municipal bond projected for this project. The annual debt service portion attributed to the cost to install traffic signals is approximately $25,000. The total anticipated debt service for the Windsor Road Improvement Project is $320,000 annually for ten years.

RECOMMENDATION

It is recommended that traffic signals be installed at the Windsor Road and Race Street intersection with the upcoming Windsor Road Improvement Project.

Attachments: A – May 5, 2014 Hanson memorandum to City of Urbana
B – Federal Highway Administration Traffic Signal Briefing Sheet

HANSON

MEMORANDUM

TO: City of Urbana

FROM: Hanson Professional Services

DATE: 5/5/2014

SUBJECT: Traffic Projections and Analysis for Windsor Road Reconstruction Project, Urbana, Illinois
Hanson No. 13L0201
Section No. 13-00540-00-PV

Project Description

The City of Urbana plans to reconstruct four travel lanes, approximately 5,860 feet in length, from Philo Road to Race Street. The existing pavement (completed in 1992) is prematurely deteriorating, possibly from an alkali silica chemical reaction based on a D-Cracking Investigation Report completed in 2006 by Engineering and Research International, Inc. for the City of Urbana. The reconstructed road would remain four lanes (two eastbound and two westbound lanes) and the overall roadway width is proposed to remain the same. Lane widths will be reduced from 12 feet to 11 feet, but the median width will be increased to 8 feet and constructed as a raised median. Underdrains will be installed along the outside of the proposed pavement, and traffic signals will be installed at Race Street and Windsor Road. The existing traffic signal and street lighting configuration at Philo Road will remain the same. All sidewalks, multi-use paths, crosswalks, and ramps will be reviewed for PROWAG compliance.

Existing Traffic

Existing 12-hour turning movement traffic counts were taken at the intersections of Windsor Road and Race Street, the Clark-Lindsey Village Entrance on February 26, 2014. Traffic counts along with pedestrian counts were taken at the Vine Street intersection on April 16, 2014. These counts can be seen in Exhibit 1.

It was anticipated that there may be a higher traffic demand for Windsor Road than the counts would reflect due to drivers choosing an alternate route based on the poor condition of Windsor Road. The 2012 traffic study conducted by Eriksson Engineering Associates for the expansion of the Clark Lindsey Village was examined to verify the count data along Windsor Road. This assumption was proved to be correct, as the 2012 traffic counts at the intersection of Windsor Road and Race Street were significantly higher, over 50%, for the traffic using Windsor Road. These numbers are consistent with the 2006 Vine Street and Windsor Road intersection Study conducted by CUUATS.

Therefore, to accurately analyze existing roadway operations when the alternate routes would no longer be necessary, the 2012 numbers were used where discrepancies existed between the 2012 and 2014 traffic counts.

Traffic at the intersection of Windsor Road and Philo Road was established by growing an existing 2004 IDS for this intersection and growing the traffic at an annual 1% growth rate, and balanced with the existing traffic data to arrive at the 2014 levels.

Proposed Traffic

The traffic from two proposed developments, the Clark-Lindsey expansion and the Verdant Prairies Villages, were added to the existing traffic to arrive at an existing plus developed 2014 traffic projection. The 2012 traffic study was reviewed and Hanson concurs with their traffic projections. These study projections were used for the Clark-Lindsey expansion, and the conservative assumption of 50 Condominium/Townhomes (ITE Trip Generation Manual 231) was used for the Verdant Prairies Village development. The Verdant Parries Village is projected to have 40 AM peak hour trips (30 egress/10 ingress) as well as 40 PM trips (17 egress/23 ingress). These projections were combined with the Existing traffic counts in Exhibit 2.

A 20-year design horizon (2034) was projected to understand the long range operations of the Windsor Road and its intersections. All traffic intersection traffic at Philo Road and Race Street was grown at a 1% annual growth rate. The traffic accessing the two developments and Vine Street remained the same, as there is no sizable land use growth potential at these locations. These projections can be seen in Exhibit 3.

Signal Warrant

The intersection of Windsor Road and Race Street is currently 4-way stop controlled. Windsor Road is a 5-lane arterial road. Race Street is a 2-lane collector, with a three lane section at the intersection of Windsor Road. The stop control for Windsor Road is unusual for this classification of roadway, and does not meet with driver expectations. This location is the only unsignalized 4-way intersection between IL 130 (High Cross Road) to the east and US 45 (Neil Street) to the west, a distance of 4.5 miles. The Highway Capacity Manual and Software does not even analyze a stop condition for this cross section. This type of intersection traffic control is not recommended for this roadway configuration; because it can lead to crashes due to the fact that it can be unanticipated by drivers and stop signs may not be noticed by the drives in the leftmost through lane and the left turn lane. Modifying the intersection so that it can be analyzed, the capacity of this 4-way stop was analyzed using HCS software and there are failures and LOS F in the 2014 and 2034 condition.

A traffic signal warrant was conducted at this intersection. Traffic signal warrants are listed in the Manual on Uniform Traffic Control Devices (MUTCD). The most common warrant used for traffic signalization is Warrant 1, Eight-Hour Vehicular Volume. The 12-hour traffic counts show the 8th highest hour traffic volume occurs at 4:00 – 5:00. Even with the lower traffic numbers for reasons stated earlier, this intersection meets Warrant 1. The more realistic 2014 traffic projection, when true demand is realized post construction, and will meet both warrants. A signal warrant analysis was also conducted at Windsor Road and Vine Street intersection. This intersection did not meet Warrants.

Table 1 Traffic Signal Warrant Volumes

Windsor Road and Race Street	*8th Highest Hourly Volume*	*4th Highest Hourly Volume*
Winsor Road (Both Approaches)	895	952
Race Street (Higher Volume Approach)	201	208

Windsor Road and Vine Street	*8th Highest Hourly Volume*	*4th Highest Hourly Volume*
Winsor Road (Both Approaches)	803	859
Vine Street (Higher Volume Approach)	72	86

Table 4C-1. Warrant 1, Eight-Hour Vehicular Volume

Condition A—Minimum Vehicular Volume

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	500	400	350	280	150	120	105	84
2 or more	1	600	480	420	336	150	120	105	84
2 or more	2 or more	600	480	420	336	200	160	140	112
1	2 or more	500	400	350	280	200	160	140	112

Condition B—Interruption of Continuous Traffic

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	750	600	525	420	75	60	53	42
2 or more	1	900	720	630	504	75	60	53	42
2 or more	2 or more	900	720	630	504	100	80	70	56
1	2 or more	750	600	525	420	100	80	70	56

[a] Basic minimum hourly volume

[b] Used for combination of Conditions A and B after adequate trial of other remedial measures

[c] May be used when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

[d] May be used for combination of Conditions A and B after adequate trial of other remedial measures when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

Sect. 4C.02 December 2009

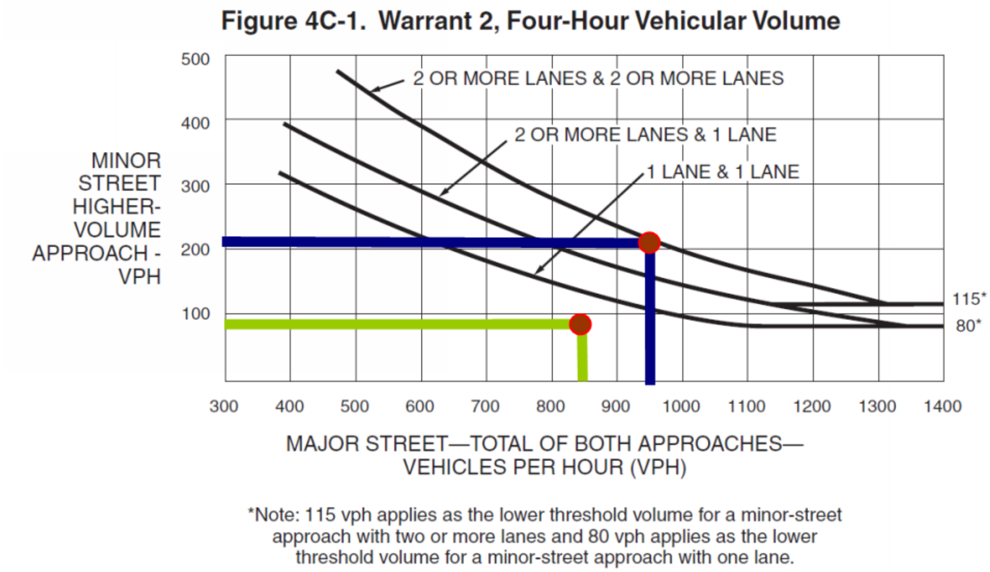


Table 2 LOS Windsor and Race Signal

Race Street	*2014 LOS (Delay)*		*2034 LOS (Delay)*	
	AM	**PM**	**AM**	**PM**
East Leg	B (11.7)	B (17.5)	B (13.8)	C (31.6)
West Leg	B (18.2)	B (15.1)	C (25.8)	C (20.1)
North Leg	B (19.3)	C (20.1)	B (19.5)	B (18.87)
South Leg	C (25.8)	C (25.7)	C (27.1)	C (29.6)
INTERSECTION TOTAL	B (17.5)	B (18.3)	C (21.6)	C (27.2)

Turn Lane Analysis

The intersection driveways at the Clark-Lindsey expansion and the Verdant Prairies Villages of developments mentioned above were analyzed to see if additional turn lanes are warranted. The criterion for the addition of a left turn lane is found in Chapter 34 of the IDOT Bureau of Local Roads and Streets Manual. It states:

"34-3.01(b) Left-Turn Lanes

The accommodation of left turns is often the critical factor in proper intersection design. Left-turn lanes can significantly improve both the level of service and intersection safety. In general, use an exclusive left-turn lane at all intersections on highways with a median wide enough to accommodate a left-turn lane, regardless of traffic volumes. Consider using an exclusive left-turn lane for the following:

- *at any signalized intersection where the left-turning volume is equal to or greater than 75 vehicles per hour for a single turn lane or 300 vehicles per hour for a dual turn lane;*
- *any intersection where a capacity analysis determines a left-turn lane or dual left-turn lanes are necessary to meet the level-of-service criteria;*
- *for uniformity of intersection design along the highway if other intersections have left-turn lanes (i.e., to satisfy driver expectancy); or*

- *any intersection where the crash experience, traffic operations, sight distance restrictions (e.g., intersection beyond a crest vertical curve), or engineering judgment indicates a significant conflict related to left-turning vehicles."*

The low volumes of these two driveways do not warrant turn lanes. (See Exhibits 2 and 3) Furthermore, a Synchro/SimTraffic microsimulation model was run for the entire corridor in both the 2014 and the 2034 design year, and these driveways, without left turn lanes, do not inhibit the overall functionality or traffic progression of Windsor Road.

Crosswalk at Vine Street

A pedestrian count at the intersection of Vine Street and Winsor Road was conducted. The count revealed 84 pedestrians crossing Windsor Road throughout the 12-hour count, and 20 during the peak hour. The CUUATS Study completed in March 2006 for this intersection showed and peak hour volume of 32 pedestrians crossing Windsor Road. Neither of these volumes meets the MUTCD Warrant 4, Pedestrian Peak Hour, for a traffic signal at this intersection, where the minimum amount of pedestrians needed to meet the Warrant is 75. According to Table 13-2 of the ITE Traffic Control Devices Handbook, 2nd Edition, "Marked Crosswalks Alone are Insufficient" given volume, geometric, and speed parameters at this location. A Rectangular Rapid Flash Beacon (RRFB) is a newer device increasing in popularity. The RRFB alerts drivers to the presence of pedestrians within the crosswalk. It is recommended that the RRFB and crosswalk signs be used on both the right and left side of the traveled way, as suggested in the FHWA *Interim Approval for Optional Use of Rectangular Rapid Flashing Beacons (IA-11).* These beacons could be either solar powered or hard wired and push button activated.

Turn Lane Storage Lengths

Figure 34-3D of the BLR requires a minimum storage length of 115' for the intersection of Windsor Road and Race Street and Windsor Road and Philo Road. The existing north and west legs of Philo Road each have a storage length of 150'. This is proposed to be maintained. An HCS analysis was conducted at these intersections using both the 2014 traffic volumes and the 2034 traffic volumes, Exhibits 2 and 3. The 95% back of queue from this analysis can be seen in Table 3.

Table 3 95% Back of Queue

Race Street	*2014 AM(PM)*	*2034 AM(PM)*
North Leg	75 (20)	95 (23)
South Leg	10 (23)	10 (25)
East Leg	33 (38)	43 (50)
West Leg	8 (13)	10 (18)

Philo Road	*2014 AM(PM)*	*2034 AM(PM)*
North Leg	25 (18)	30 (18)
South Leg	20 (75)	23 (85)
East Leg	35 (85)	48 (133)
West Leg LT	0 (3)	3 (5)
West Leg RT	45 (48)	63 (65)

As can be seen, the 115' requirement is adequate for all storage lengths for the 2014 traffic volumes. The east leg of the Philo Road intersection may exceed the 115' of storage in the 2034 design year if the predicted traffic growth materializes.

Traffic During Construction and Winter Shutdown

The construction staging proposed reduces Windsor Road to one lane in each direction, and maintains this configuration over the winter between construction of the northern and southern halves of the roadway. All turning movements at intersections and driveways will remain open. A Synchro/SimTraffic model was run for the one lane construction staging scenario. The model revealed that Windsor Road, with one lane in each direction, can successfully handle the **2014 counted volume**. The westbound leg of the Windsor Road Race Street intersection will operate at a failing level of service under this configuration in the AM, as well as the eastbound leg in the PM. The traffic signal operation at the intersection of Philo Road and Windsor Road will need to be modified. The protected left turn phase for the east and west legs will need to be eliminated because there is no dedicated left-turn lane. This intersection will operate at an LOS C in the AM and PM under this configuration; however, some queuing may occur for the eastbound and westbound legs while through vehicles are waiting for a left turning vehicle to progress through the intersection. They Synchro/SimTraffic model showed no blocking or stacking over adjacent roads or driveways.

Crash Analysis

Crash report data for the Windsor Road study corridor was retrieved from the City of Urbana, along with the Illinois Department of Transportation's Safety Data Mart, for the years 2009 through 2013, to determine if there were large amounts of crashes or any recognizable crash patterns. Each crash report was reviewed to determine the type, cause, crash trends, and injuries that occurred. Table 4 shows this information.

There are few injury crashes in this corridor. Weather, animals, or driver impairment are factors in four of the nine injury crashes. A relatively high number of crashes, including five failing to yield to right-of-way or improper lane usage causes, occur at Windsor Road and Race Street. This is likely due to the unconventional stop sign along Windsor Road and the poor level of service. The traffic signal should lower the occurrence of this type of crash.

Table 4 Crash Data

Race Street

Year	Injury	Lighting Condition	Pavement Condition	Crash Type	Cause
2009	PDO	Daylight	Wet	Animal	Animal
2009	PDO	Daylight	Dry	Angle	Unable to Determine
2009	PDO	Daylight	Dry	Rear End	Failing to reduce speed to avoid crash
2009	PDO	Daylight	Dry	Rear End	Failing to reduce speed to avoid crash
2009	PDO	Daylight	Wet	Turning	Failing to yield right-of-way
2009	PDO	Daylight	Dry	Animal	Disregarding Stop Sign
2010	B-Non-incapacitating injury crash	Daylight	Dry	Rear End	Following too closely

Year	Injury	Lighting Condition	Pavement Condition	Crash Type	Cause
2010	B-Non-incapacitating injury crash	Daylight	Dry	Overturned	Evasive action due to animal, object, nonmotorist
2010	B-Non-incapacitating injury crash	Darkness	Snow or Slush	Pedestrian	Weather
2011	PDO	Daylight	Dry	Rear End	Failing to reduce speed to avoid crash
2011	PDO	Daylight	Dry	Turning	Failing to yield right-of-way
2011	PDO	Dusk	Dry	Rear End	Failing to reduce speed to avoid crash
2011	PDO	Daylight	Dry	Turning	Failing to yield right-of-way
2011	PDO	Daylight	Rain	Turning	Failing to yield right-of-way
2012	PDO	Daylight	Dry	Sideswipe Same direction	Improper Lane Usage
2013	PDO	Darkness	Wet	Fixed Object	Exceeding safe speed for conditions
2013	PDO	Darkness	Dry	Animal	Animal

Philo Road

Year	Injury	Lighting Condition	Pavement Condition	Crash Type	Cause
2009	A - Incapacitating Crash	Daylight	Snow or Slush	Turning	Failing to yield right-of-way
2009	B-Non-incapacitating injury crash	Daylight	Dry	Fixed Object	Driving Skills/knowledge experience
2009	PDO	Daylight	Dry	Angle	Disregarding Traffic Signals
2009	PDO	Daylight	Dry	Rear End	Failing to reduce speed to avoid crash
2009	PDO	Daylight	Dry	Fixed Object	Failing to reduce speed to avoid crash
2010	PDO	Daylight	Dry	Rear End	Failing to reduce speed to avoid crash
2010	PDO	Daylight	Dry	Angle	Improper Braking
2011	A - Incapacitating Crash	Daylight	Dry	Angle	Disregarding Traffic Signals
2012	PDO	Daylight	Dry	Turning	Failing to yield right-of-way
2013	PDO	Daylight	Dry	Angle	Disregarding Traffic Signals
2013	B-Non-incapacitating injury crash	Daylight	Dry	Pedalcyclist	Disregarding Traffic Signals
2013	B-Non-incapacitating injury crash	Daylight	Dry	Pedalcyclist	Disregarding Traffic Signals

Vine Street

Year	Injury	Lighting Condition	Pavement Condition	Crash Type	Cause
2009	B-Non-incapacitating injury crash	Daylight	Dry	Turning	Failing to yield right-of-way
2010	PDO	Daylight	Dry	Turning	Failing to yield right-of-way
2010	PDO	Darkness	Wet	Fixed Object	Under the influence alcohol/drugs
2011	PDO	Daylight	Wet	Turning	Failing to yield right-of-way
2013	PDO	Daylight	Dry	Rear End	Following too closely

Lynn Street

Year	Injury	Lighting Condition	Pavement Condition	Crash Type	Cause
2010	PDO	Daylight	Dry	Rear end	Failing to reduce speed to avoid crash
2012	B-Non-incapacitating injury crash	Darkness, Lighted Road	Dry	Fixed Object	Under the influence alcohol/drugs

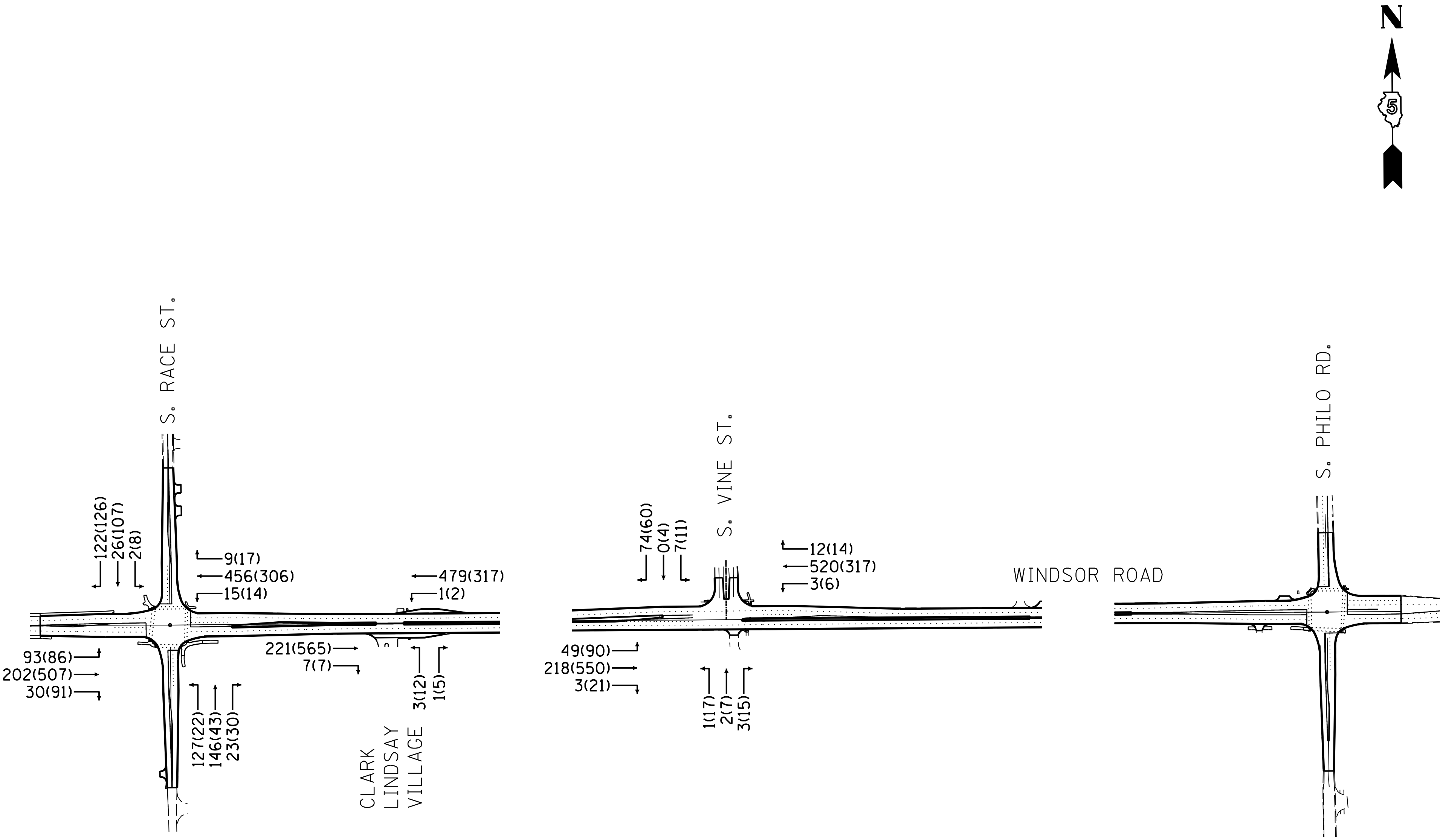
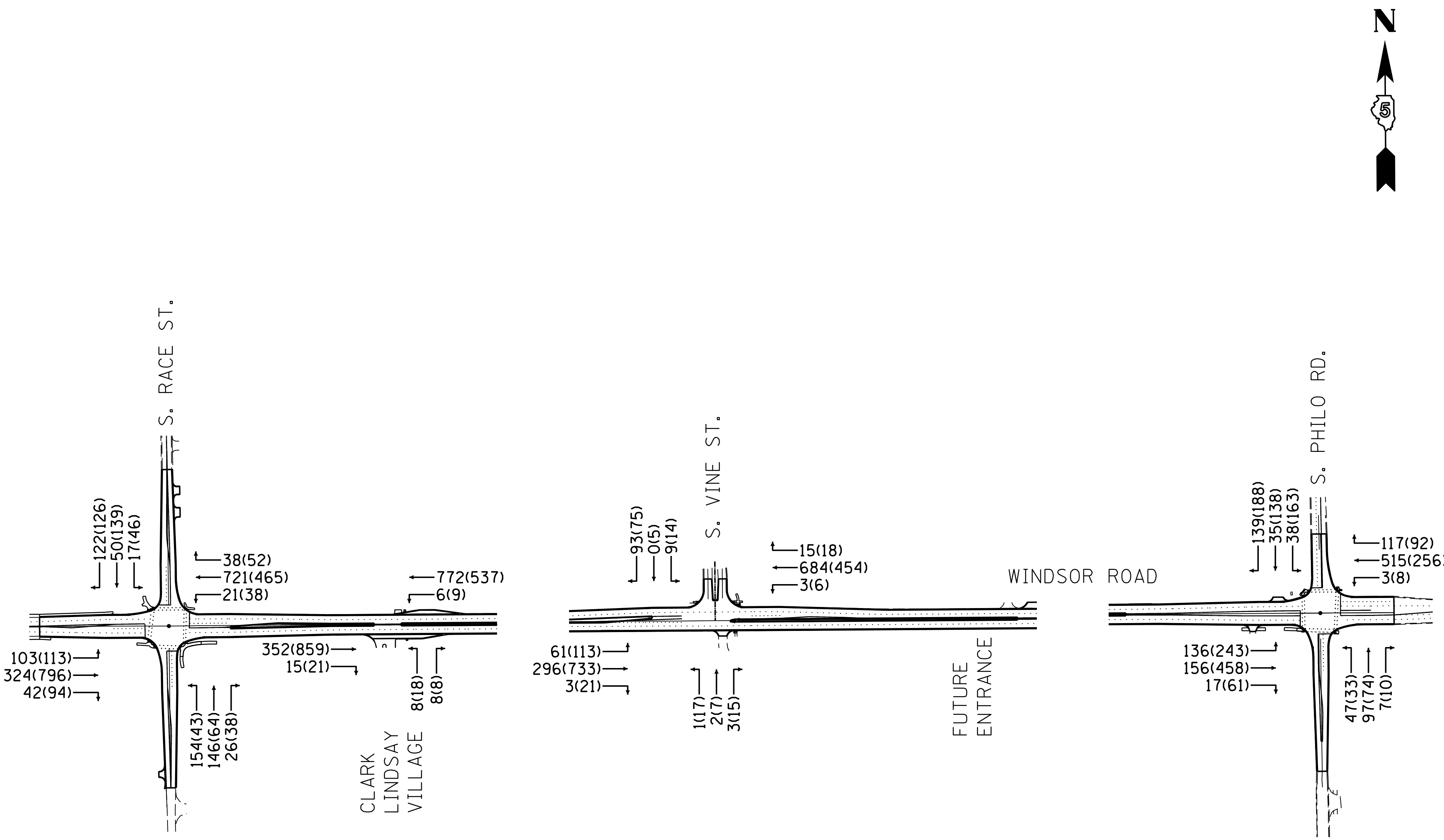


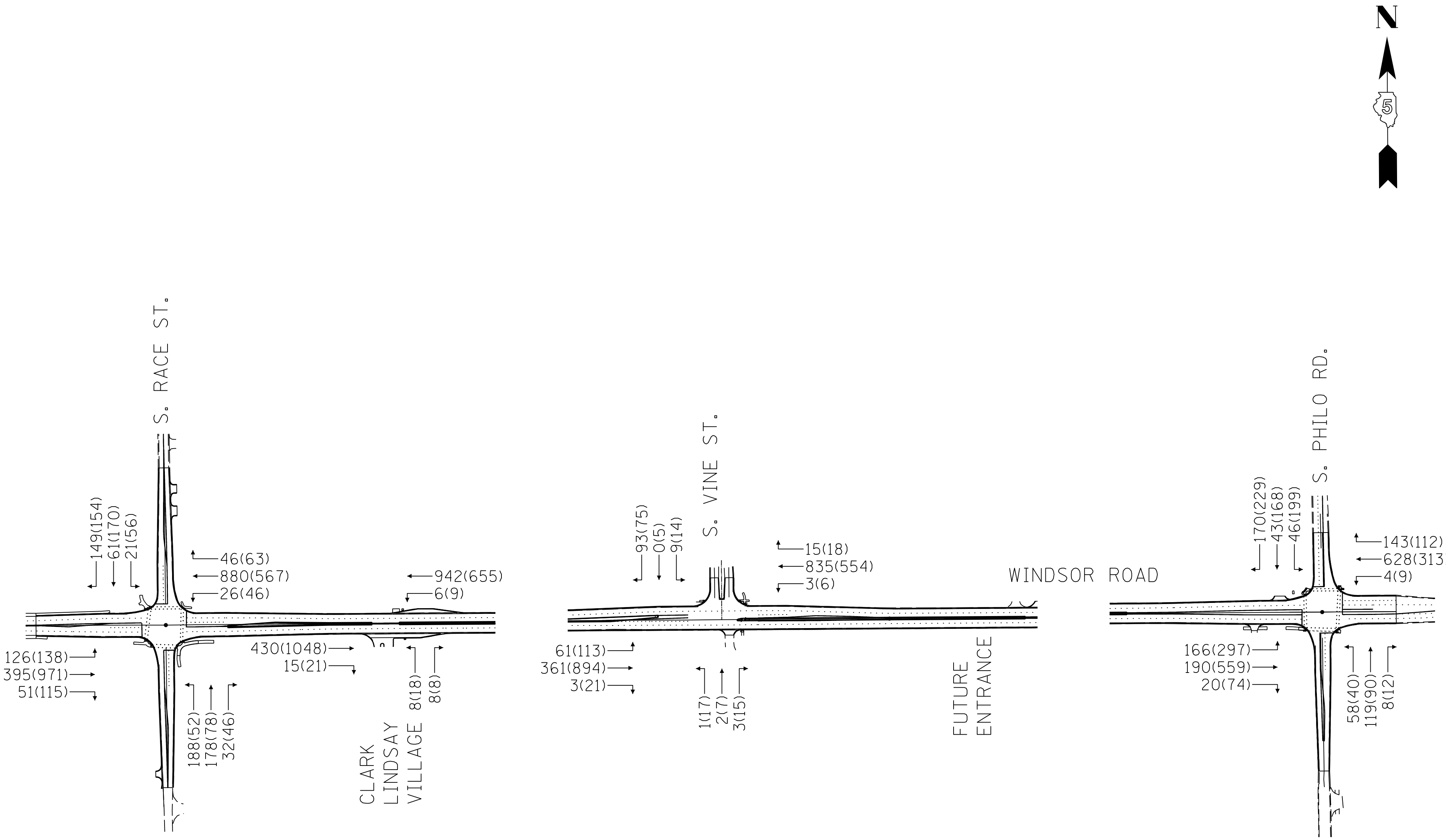
EXHIBIT 1
WINDSOR ROAD
TRAFFIC COUNTS
EXISTING CONDITIONS

HANSON



HANSON

EXHIBIT 2
WINDSOR ROAD
TRAFFIC COUNTS
2014 DESIGN



HANSON

EXHIBIT 3
WINDSOR ROAD
TRAFFIC COUNTS
2034 DESIGN

Traffic Signals

The introduction to this issue brief provides an overview of traffic signals (purpose, warrants for signal installation, advantages, disadvantages, and factors to consider) followed by an introduction to the contents of this issue brief (crash reduction factors, presentation of the crash reduction factors, and using the tables).

Purpose of Traffic Signals

Traffic signals are used to assign vehicular and pedestrian right-of-way. They are used to promote the orderly movement of vehicular and pedestrian traffic and to prevent excessive delay to traffic.

Traffic signals should not be installed unless one of the warrants specified by the *Manual on Uniform Traffic Control Devices* (MUTCD) has been satisfied. The satisfaction of a warrant is not in itself justification for a signal. A traffic engineering study must be conducted to determine whether the traffic signal should be installed. The installation of a traffic signal requires sound engineering judgment, and must balance the following, sometimes conflicting, goals:

- Moving traffic in an orderly fashion.
- Minimizing delay to vehicles and pedestrians.
- Reducing crash-producing conflicts.
- Maximizing capacity for each intersection approach.

Where Should a Signal Be Installed?

The MUTCD lists eight warrants for the placement of traffic signals. Readers are encouraged to review Part 4 of the MUTCD for more specific information regarding signal warrants. Access management considerations and the spacing of signals on arterial roadways are critical elements of system efficiency and operational safety. The basic question that must be answered is, “Will this intersection operate better with or without a traffic signal?”

Advantages of Signals

Traffic signals that are properly located and operated are likely to:

- Provide for orderly movement of traffic.
- Increase traffic capacity of the intersection.
- Reduce the frequency of certain types of crashes (e.g. right-angle crashes).
- Provide for continuous or nearly continuous movement of traffic along a given route.
- Interrupt heavy traffic to permit other traffic, vehicular or pedestrian, to cross.

Disadvantages of Signals

Traffic control signals are often considered a panacea for all traffic problems at intersections. This belief has led to the installation of traffic control signals at many locations where they are not needed and where they may adversely affect the safety and efficiency of vehicular, bicycle, and pedestrian traffic.

Even when justified by traffic and roadway conditions, traffic control signals can be ill designed, ineffectively placed, improperly operated, or poorly maintained. Unjustified or improper traffic control signals can result in one or more of the following disadvantages:

U.S. Department of Transportation
Federal Highway Administration
Safe Roads for a Safer Future
Investment in roadway safety saves lives
FHWA-SA-10-005

- Excessive delay.
- Excessive disobedience of the signal indications.
- Increased use of less adequate routes as road users attempt to avoid the traffic control signals.
- Significant increases in the frequency of crashes (especially rear-end crashes).

As angle crashes tend to be more severe than rear-end crashes, traffic engineers are usually willing to trade off an increase in the number of rear-end crashes for a decrease in the number of angle crashes, but if an intersection does not have an angle-crash problem, the tradeoff does not apply, and the installation of traffic signals can actually cause a deterioration in the overall safety at the intersection.

Factors to Consider when Installing a Signal

A number of factors should be considered when planning to signalize an intersection. These factors include:

- The negative effects of traffic delay. Excessive delay results in significant fuel waste, higher motorist costs, and air pollution.
- Potential diversion of arterial traffic into neighborhood streets.
- Red-light running violations and associated crashes.
- Cost. The cost for a signal ranges from $50,000 to more than $200,000 depending on the complexity of the intersection and the characteristics of the traffic using the intersection. In addition, the annual operating cost of each signal ranges from $1,000 to $5,000.

Signal Improvements That May Decrease Crashes

The following changes may decrease crashes:

- Signal retiming, phasing, and cycle improvements;
- Review and assurance of adequacy of yellow change interval/all-red clearance interval for safer travel through the intersection;
- Use of longer visors, louvers, backplates, and reflective borders;
- Installation of 12-inch signal lenses;
- Installation of additional signal heads for increased visibility;
- Provision of advance detection on the approaches so that vehicles are not in the dilemma zone when the signal turns yellow;
- Repositioning of signals to overhead (mast arm) instead of pedestal-mounted;
- Use of double red signal displays; and
- Removal of signals from late-night/early-morning programmed flash.

Introduction to the Contents of this Issue Brief

This issue brief documents estimates of the crash reduction that might be expected if a specific countermeasure or group of countermeasures is implemented with respect to traffic signals. The crash reduction estimates are presented as crash reduction factors (CRFs).

Traffic engineers and other transportation professionals can use the information contained in this issue brief when asking the following types of question: Which countermeasures might be considered at the signalized intersection of Maple and Elm streets, an intersection that is experiencing a high number of crashes? What changes in the number of crashes are possible with the various countermeasures?

Crash Reduction Factors

A CRF is the percentage crash reduction that might be expected after implementing a given countermeasure. In some cases, the CRF is negative (i.e., the implementation of a countermeasure is expected to lead to a percentage increase in crashes).

One CRF estimate is provided for each countermeasure. Where multiple CRF estimates were available from the literature, selection criteria were used to choose which CRFs to include in the issue brief:

- Firstly, CRFs from studies that took into account regression to the mean and changes in traffic volume were preferred over studies that did not.
- Secondly, CRFs from studies that provided additional information about the conditions under which the countermeasure was applied (e.g. road type, area type) were preferred over studies that did not.

Where these criteria could not be met, a CRF may still be provided. In these cases, it is recognized that the reliability of the estimate of the CRF is low, but the estimate is the best available at this time. The CRFs in this issue brief may be periodically updated as new information becomes available.

The *Desktop Reference for Countermeasures* lists all of the CRFs included in this issue brief and adds many other CRFs available in the literature. A few CRFs found in the literature were not included in the *Desktop Reference*. These CRFs were considered to have too large a range or too large a standard error to be meaningful, or the original research did not provide sufficient detail for the CRF to be useful.

A CRF should be regarded as a generic estimate of the effectiveness of a countermeasure. The estimate is a useful guide, but it remains necessary to apply engineering judgment and to consider site-specific environmental, traffic volume, traffic mix, geometric, and operational conditions that will affect the safety impact of a countermeasure. The user must ensure that a countermeasure applies to the particular conditions being considered. The reader is also encouraged to obtain and review the original source documents for more detailed information and to search databases such as the National Transportation Library (http://ntlsearch.bts.gov) for information that becomes available after the publication of this issue brief.

Presentation of the Crash Reduction Factors

In the Table presented in this issue brief, the crash reduction estimates are provided in the following format:

CRF(standard error)^REF

The CRF is the value selected from the literature.

The use of the color blue and the italicizing of words used in the text (except for words associated with a specific document) are associated with new information provided by the Highway Safety Manual*, April 2009 draft, as listed in Reference 21 at the end of this issue brief.*

The standard error is given where available. The standard error is the standard deviation of the error in the estimate of the CRF. The true value of the CRF is unknown. The standard error provides a measure of the accuracy of estimate of the true value of the CRF. *The August 2008 edition of Issue Brief 5 used the phrase "relatively small" to indicate that a CRF is "relatively accurately known." Relatively small was not explicitly defined several years ago; however, its intention is congruent with the definition used in this edition of the Issue Brief: relatively small is defined as a CRF with a standard error ≤10. This is equivalent to the* Highway Safety Manual *AMF's (Accident Modification Factors) with standard errors of ≤0.10.*

A "relatively large" standard error *associated with a CRF is defined as >10* and indicates that the CRF is "not accurately known."

The standard error may be used to estimate a confidence interval of the true value of the CRF. (An example of a confidence interval calculation is given below.)

The ^REF is the reference number for the source information.

As an example, the CRF for the countermeasure "provide protected left-turn phase for left-turn fatal/injury crashes" is:

17*(4)*[21]

The following points should be noted:

- *The CRF of 17 means that a 17% reduction in fatal and injury crashes combined is expected after providing a protected left-turn phase.*
- This CRF is bolded which means that a) a rigorous study methodology was used to estimate the CRF, and b) *the standard error is ≤10.* A CRF which is not bolded indicates that a less rigorous methodology (e.g. a simple before-after study) was used to estimate the CRF and/ or the standard error is large compared with the CRF.
- *The standard error for this CRF is 4*. Using the standard error, it is possible to calculate the 95% confidence interval for the potential crash reduction that might be achieved by implementing the countermeasure. The 95% confidence interval is ±2 standard errors from the CRF. *Therefore, the 95% confidence interval for providing a protected left-turn phase is between 9% and 25% (17 – (2×4) = 9%, and 17 + (2×4) = 25%).*
- *The reference number is 21 (*Highway Safety Manual*, April 2009 draft, as listed in the references at the end of this issue brief).*

Using the Table

The CRFs for traffic signal-related crashes are presented in the Signalization Countermeasures Table that summarizes the available information.

Readers familiar with the previous editions of this issue brief will notice the following changes:

- Countermeasure cost estimates of low, medium, high are no longer provided, as most agencies have readily available cost estimate information with actual dollar amounts.

- Countermeasures that do not have an estimate of crash-reduction effectiveness are no longer included.

Table 1, Signalization Countermeasures is divided into three sections: signal operations countermeasures; signal hardware countermeasures; and combination signal and other countermeasures. This table is also found in Issue Brief No.8, which includes a more comprehensive toolbox of countermeasures for consideration at intersections.

The following points should be noted:

- Where available, separate CRFs are provided for different crash severities. The levels of crash severity are as follows: all, fatal/ injury, fatal, injury, or property damage only (PDO).
- Where available, existing traffic control information is provided (i.e., the conditions existing before implementation of a countermeasure). The control information is signal where the countermeasure involved a change to existing signalization. The control information is no signal or stop where the countermeasure involved a change from an unsignalized intersection to a signalized intersection.
- Where available, configuration information is provided. Two types of configuration are identified in the studies used for the CRFs: 3-leg and 4-leg.
- Where available, the table provides daily traffic volume (vehicles/day) information for the major and minor roads of the intersection where the potential effectiveness of the countermeasure was measured. Where only one volume is provided, this volume refers to the traffic volume on the major road, unless otherwise specified.
- Blank cells mean that no information is reported in the source document.
- For additional information, please visit the FHWA Office of Safety Web site (http://safety.fhwa.dot.gov).

Legend

CRF(standard error)[REF]

CRF is a crash reduction factor, which is an estimate of the percentage reduction that might be expected after implementing a given countermeasure. A number in bold indicates a rigorous study methodology and a small standard error *(≤10)* in the value of the CRF. Standard error, where available, is the standard deviation of the error in the estimate of the CRF.

[REF] is the reference number for the source information.

Additional crash types identified in the Other Crashes column:
a: Head-on
b: Run-off-road
c: Overturn
d: Night
e: Day
f: Multiple-vehicle
g: Fixed-object
h: Older-driver
i: Younger-driver
j: Right-turn
k: Pedestrian
l: Emergency vehicle

TABLE 1: SIGNALIZATION COUNTERMEASURES

Countermeasures	Crash Severity	Control	Area Type	Configuration	All Crashes	Left-Turn Crashes	Rt-Angle Crashes	Rear-end Crashes	Sideswipe Crashes	Other Crashes	Major/Minor Daily Traffic Volume (vehicles/day)
SIGNAL OPERATIONS COUNTERMEASURES											
Add all-red clearance interval (from 0 to 1 second)	All	Signal	Urban								
Add exclusive pedestrian phasing	All	Signal					0 (44) [14]			k 34 [7]	
Convert exclusive leading protected to exclusive lagging protected	All	Signal			-15(19) [6]	-49(54) [6]					
Convert permissive or permissive/protected to protected only left-turn phasing	All					99 [20]					
Convert permissive to permissive/ protected left-turn phasing	All					16 [20]					
Convert protected left-turn phase to protected/permissive	All	Signal			-20(17) [15]	-65(71) [6]		4(22) [6]			
	Fatal/Injury	Signal			-10(25) [15]						
Convert permissive to protected	*All*	*Signal*	*Urban*	*4-leg or 3-leg*	***6*** *(10)* [21]	***99*** *(1)* [21]					
Convert permissive to protected/permissive or permissive/protected phasing	*Injury*	*Signal*	*Urban*	*4-leg*		***16*** *(2)* [21]					*3,000-77,000/10-45,500*
Convert permissive to protected/permissive or permissive/protected phasing	*All*	*Signal*	*Urban*	*4-leg*	*1* [21]						
Convert permissive to protected left-turn phase on multiple approaches	*All*	*Signal*		*on 1 approach*	*6* [21]						
	All	*Signal*		*on 2 approaches*	*11* [21]						
	All	*Signal*		*on 3 approaches*	*17* [21]						
	All	*Signal*		*on 4 approaches*	*22* [21]						

Countermeasures	Crash Severity	Control	Area Type	Configuration	All Crashes	Left-Turn Crashes	Rt-Angle Crashes	Rear-end Crashes	Sideswipe Crashes	Other Crashes	Major/Minor Daily Traffic Volume (vehicles/day)
SIGNAL OPERATIONS COUNTERMEASURES											
Convert permissive to protected/permissive or permissive/protected left turn phase on multiple approaches	*All*	*Signal*		*on 1 approach*	*1* [21]						
	All	*Signal*		*on 2 approaches*	*2* [21]						
	All	*Signal*		*on 3 approaches*	*3* [21]						
	All	*Signal*		*on 4 approaches*	*4* [21]						
Convert protected/permissive left-turn phase to permissive/protected	All	Signal			-13(19) [8]	33(22) [8]					
Improve signal timing [to intervals specified by the ITE Determining Vehicle Change Intervals: A Proposed Recommended Practice (1985)]	All	Signal		4-Leg	**8**(9) [15]		4(18) [15]	-12(16) [15]		h 42 [12]	
	All	Signal	All							f 5 [5]	
	All	Signal				75 [4]					
	Fatal/Injury	Signal				55 [4]	30 [4]			a 75 [4]	
	Fatal/Injury	Signal								b 62 [4]	
	Fatal/Injury	Signal		4-Leg	12 (9) [15]		-6 (22) [15]	-8 (17) [15]			
	Fatal/Injury	Signal	All							f 9 [5]	
	Fatal/Injury	Signal								k 37 [15]	
	PDO	Signal				63 [4]	46 [4]	17 [4]		b 28 [4]	
Increase yellow change interval	All	Signal			15 [4]		30 [4]				
Install emergency vehicle pre-emption systems	All									l 70 [16]	
Modify signal phasing (implement a leading pedestrian interval)	All	Signal								k 5 [7]	
Provide actuated signals	All	Signal				80 [4]	10 [4]				
Provide Advanced Dilemma Zone Detection for rural high speed approaches	Fatal/Injury	Signal	Rural	4-Leg (1 app)	39 [19]						
Provide protected left-turn phase	Fatal/Injury	Signal	Urban			***17*** *(4)* [21]	***25*** *(2)* [21]				
	All	Signal			30 [4]	41 [4]	54 [4]	27 [4]		c 27 [4]	<5,000/ lane(Total)
	All	Signal			36 [4]	46 [4]	56 [4]	35 [4]		c 35 [4]	>5,000/ lane(Total)
	All	Signal			27 [4]	48 [4]	63 [4]	31 [4]		c 31 [4]	
Provide protected/permissive left turn phase (leading green arrow)	Fatal/Injury	Signal	Urban			**17** *(2)* [9]	**25** (2) [9]				
Provide signal coordination	All	Signal					32 [7]				
Provide split phases	All	Signal			25 [7]						
Remove flash mode (late night/ early morning)	All	Signal			29 [7]		75 (19) [14]				
Replace existing WALK / DON'T WALK signals with pedestrian countdown signal heads	All	Signal	Urban							k 25 [10]	

Countermeasures	Crash Severity	Control	Area Type	Configuration	All Crashes	Left-Turn Crashes	Rt-Angle Crashes	Rear-end Crashes	Sideswipe Crashes	Other Crashes	Major/Minor Daily Traffic Volume (vehicles/day)
SIGNAL HARDWARE COUNTERMEASURES											
Add 3-inch yellow retroreflective sheeting to signal backplates	All	Signal	Urban		15 (51) [17]						
Add additional signal and upgrade to 12-inch lenses	All	Signal		4-Leg						h 31 [12]	
	All	Signal		4-Leg						i 17 [12]	
Add signal (additional primary head)	All	Signal	Urban	4-Leg	28 [2]		35 [2]	28 [2]			
	Fatal/Injury	Signal	Urban	4-Leg	17 [2]						
	PDO	Signal	Urban	4-Leg	31 [2]						
Convert signal from pedestal-mounted to mast arm	All	Signal			49 [16]	12 [16]	74 [16]	41 [16]			
	Fatal/Injury	Signal			44 [16]						
	PDO	Signal			51 [16]						
Improve visibility of signal heads (increase signal lens size, install new backboards, add reflective tape to existing backboards, and/or install additional signal heads)	All	Signal	Urban		7 [18]					d 6 [18]	
	All	Signal	Urban							e 6 [18]	
	Fatal/Injury	Signal	Urban		3 [18]						
	PDO	Signal	Urban		9 [18]						
Improve visibility of signal heads (install two red displays in each head)	All	Signal			9 [7]		36 [7]				
Install larger signal lenses (12 inch)	All	Signal			11 [7]		46 [14]				
	All	Signal	Urban		24 [17]						
	Fatal/Injury	Signal	Urban		16 [17]						
Install signal backplates only	All	Signal			13 [7]		50 [7]				
Install signal backplates (or visors)	All	Signal					20 [4]				
Install signals	All	No Signal			33 [7]	38 [13]				j 50 [13]	
	All	No Signal			38 [4]		74 [9]	22 [9]		c 22 [4]	<5,000/ lane(Total)
	All	No Signal			20 [4]		43 [9]	20 [9]		c 20 [4]	>5,000/ lane(Total)
	All	No Signal	Rural		15 [13]						
	All	*Stop*	*Urban*	*4-leg*	***5*** *(9)* [21]		***67*** *(6)* [21]	*-143(40)* [21]			
	All	*Stop*	*Rural*	*3-leg or 4-leg*	***44*** *(3)* [21]	***60*** *(6)* [21]	***77*** *(2)* [21]	*-58(20)* [21]			*3,300-30,000/100-10,300*
	Fatal	No Signal			38 [13]						
	Fatal/Injury	Stop	Urban	3-Leg	14 (32) [11]		34 (45) [11]	-50 (51) [11]			11,750-42,000 / 900-4000
	Fatal/Injury	Stop	Urban	4-Leg	23 (22) [11]		**67** (20) [11]	-38 (39) [11]			12,650-22,400 / 2,400-3,625
	PDO	No Signal			-15 [13]						
Install signals (temporary)	Fatal/Injury	No Signal					39 [4]		50 [4]		
	PDO	No Signal				11 [4]	73 [4]			a 83 [4]	
Install signals (to have one over each approach lane	All		All				46 [3]				

Countermeasures	Crash Severity	Control	Area Type	Configuration	All Crashes	Left-Turn Crashes	Rt-Angle Crashes	Rear-end Crashes	Sideswipe Crashes	Other Crashes	Major/Minor Daily Traffic Volume (vehicles/day)
SIGNAL HARDWARE COUNTERMEASURES											
Remove unwarranted signals	All	Signal	Urban		***24*** *(9)* [21]		***24*** *(10)* [21]	*29 (20)* [21]		d 30 [5]	
	All	Signal	Urban							e 22 [5]	
	All	Signal	Urban							g 31 [5]	
	Fatal/Injury	Signal	Urban		53 [5]						
	PDO	Signal	Urban		24 [5]						
	Pedestrian	*Signal*	*Urban*	*One-lane one-way streets excluding major arterials*	*18(30)* [21]						
Replace signal lenses with optical lenses	All	Signal			17 [7]	10 [4]	10 [4]	10 [4]		a 20 [4]	
COMBINATION SIGNAL AND OTHER COUNTERMEASURES											
Install left-turn lane and add turn phase	All	Signal			58 [7]						
Install signals and add channelization	Fatal/Injury	No Signal					67 [4]		54 [4]	b 35 [4]	
	PDO	No Signal				24 [4]	63 [4]			a 27 [4]	

Note: Any CRF with a reference of 21 is added to this version of the Intersection Safety Issue Brief 5.

References

1. Bahar, G., Parkhill, M., Hauer, E., Council, F., Persaud, B., Zegeer, C., Elvik, R., Smiley, A., and Scott, B. “Prepare Parts I and II of a Highway Safety Manual: Knowledge Base for Part II”. Unpublished material from NCHRP Project 17-27, (2007)

2. Felipe, E., Mitic, D., and Zein, S. R., “Safety Benefits of Additional Primary Signal Heads.” Vancouver, B.C., Insurance Corporation of British Columbia; G.D. Hamilton Associates, (1998)

3. FHWA and Institute of Transportation Engineers, “Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running.”18 FHWA/TX-03/4027-2, Texas Transportation Institute, (2002)

4. Gan, A., Shen, J., and Rodriguez, A., “Update of Florida Crash Reduction Factors and Countermeasures to Improve the Development of District Safety Improvement Projects.” Florida Department of Transportation, (2005)

5. Harkey, D., Srinivasan, R., Zegeer, C., Persaud, B., Lyon, C., Eccles, K., Council, F. M., and McGee, H., “Crash Reduction Factors for Traffic Engineering and Intelligent Transportation System (ITS) Improvements: State of Knowledge Report.” Research Results Digest, Vol. 299, Transportation Research Board of the National Academies, (2005)

6. Hauer, E., “Left Turn Protection, Safety, Delay and Guidelines: A Literature Review.” www.roadsafe-tyresearch.com, (2004)

7. Institute of Transportation Engineers, “Toolbox of Countermeasures and Their Potential Effectiveness to Make Intersections Safer.” Briefing Sheet 8, ITE, FHWA, (2004)

8. Lee, J. C., Wortman, R. H., Hook, D. J., and Poppe, M. J., “Comparative Analysis of Leading and Lagging Left Turns.” Phoenix, Arizona Department of Transportation, (1991)

9. Lyon, C, Haq, A., Persaud, B. N., and Kodama, S. T. , “Development of Safety Performance Functions for Signalized Intersections in a Large Urban Area and Application to Evaluation of Left Turn Priority Treatment.” 2005 TRB 84th Annual Meeting: Compendium of Papers CD-ROM, Vol. TRB#05-2192,Washington, D.C., (2005)

10. Markowitz, F., Sciortino, S., Fleck, J.L., and Yee, B.M., “Pedestrian Countdown Signals: Experience with an Extensive Pilot Installation.” Institute of Transportation Engineers Journal, January 2006, pp. 43-48. Updated by Memorandum, Olea, R., “Collision changes 2002-2004 and countdown signals,”(February 7th, 2006)

11. McGee, H., Taori, S., and Persaud, B. N., “NCHRP Report 491: Crash Experience Warrant for Traffic Signals.” Washington, D.C., Transportation Research Board, National Research Council, (2003)

12. Morena, D. A., Wainwright, W. S., and Ranck, F., “Older Drivers at a Crossroads.” Public Roads, Vol. 70, No. 4, Washington, D.C., FHWA, (2007) pp. 6-15

13. Pernia, J.C., Lu, J.J., Weng, M.X., Xie, X., and Yu, Z., “Development of Models to Quantify the Impacts of Signalization on Intersection Crashes.” Florida Department of Transportation, (2002)

14. Polanis, S. F., “Low-Cost Safety Improvements. Chapter 27, The Traffic Safety Toolbox: A Primer on Traffic Safety”, Washington, D.C., Institution of Transportation Engineers (1999) pp. 265-272

15. Retting, R. A., Chapline, J. F., and Williams, A. F., “Changes in Crash Risk Following Re-timing of Traffic Signal Change Intervals.” Accident Analysis and Prevention, Vol. 34, No. 2, Oxford, N.Y., Pergamon Press, (2002) pp. 215-220

16. Rodegerdts, L. A., Nevers, B., and Robinson, B., “Signalized Intersections: Informational Guide.” FHWA-HRT-04-091, (2004)

17. Sayed, T., Leur, P. , and Pump, J., “Safety Impact of Increased Traffic Signal Backboards Conspicuity.” 2005 TRB 84th Annual Meeting: Compendium of Papers CD-ROM, Vol. TRB#05-16, Washington, D.C., (2005)

18. Sayed, T., El Esawey, M., and Pump, J., “Evaluating the Safety Impacts of Improving Signal Visibility at Urban Signalized Intersections.” 2007 TRB 86th Annual Meeting: Compendium of Papers CD-ROM, Vol. TRB#07-135, Washington, D.C., (2007)

19. Zimmerman, K. and Bonneson, J., “In-Service Evaluation of the Detection-Control System for Isolated High-Speed Intersections.” 2006 TRB 85th Annual Meeting: Compendium of Papers CD-ROM, Vol. TRB#06-1252, Washington, D.C., (2006)

20. Harkey, D., Srinivasan, R., Baek, J., Council, F. M., Eccles, K., Lefler, N., Gross, F., Persaud, B., Lyon, C., Hauer, E., and Bonneson, J. A., “Crash Reduction Factors for Traffic Engineering and ITS Improvements,” NCHRP Report No. 617, (2008)

21. *Highway Safety Manual 1st Edition*. AASHTO. April 2009 Draft.

5 ISSUE BRIEFS

U.S.Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

FHWA-SA-10-005