Chapter 1
INTRODUCTION

Background
Intersection safety is the subject of significant research among transportation engineering academics. Studies cover a wide range of subjects dealing with the causes and consequences of crashes at intersections because 21 percent of total crash fatalities occur at intersections (1, FHWA, 2008).

A two-way stop-controlled intersection is the most common type of intersection in the United States (2, Bared, 2000). In general, it involves a minor roadway with a stop-controlled approach intersecting a major roadway with no control as shown in FIGURE 1.

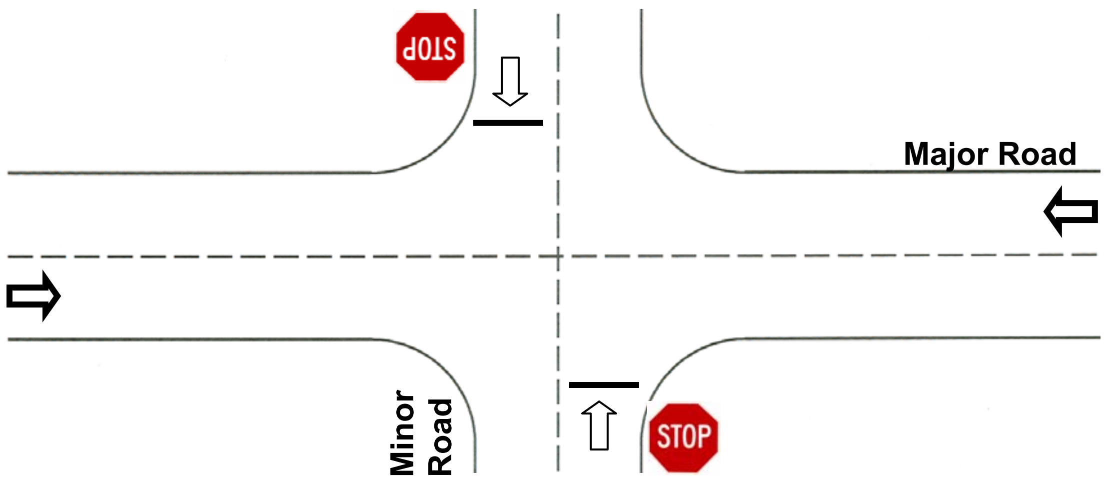


FIGURE 1 Generic Diagram of 2-Way Stop-Controlled Intersection

The major roadway generally has higher vehicular speeds, greater traffic volume, and it may be wider in cross section than the minor roadway. The stop sign requires drivers on the minor roadway to stop before traveling through the intersection. Once stopped, a driver must select a gap in the major roadway traffic stream to perform the desired crossing or turning maneuver. Researchers such as Ashworth (3, 1968), Ramsey et al, as reported by Troutbeck (4, 1975), Hewitt (5, 1983) and Fitzpatrick (6, 1991) have attempted to quantify the minimum time length of gap in the major roadway traffic stream that is acceptable to a driver stopped on the minor road to perform the most time consuming maneuver, which is the left turn movement. Their research is centered on the idea that drivers approach a stop-controlled intersection with a preconceived “critical time gap” judged as sufficient to perform their desired movement. However, the gap acceptance theory is based upon the assumption that drivers have adequate sight distance from their stopped position. Unsafe driving conditions at intersections can result from insufficient sight distance, which may result in drivers accepting gaps that are shorter than required for completion of their desired maneuver.

Research Project Purpose
Conversion of single lane approaches of two-way stop-controlled intersections to multiple-lane approach (MLA) stop-controlled intersections may result in unsafe traffic conditions if the three-dimensional geometric features of the stopped approach aren't appropriately designed. FIGURE 2 shows a sketch illustrating reasons for concern. Drivers stopped adjacent to each other on multiple-lane approaches at a stop sign can obstruct one another's view of approaching through traffic on the major road with their vehicles, which can potentially lead to unsafe driving conditions. This occurrence is even more of a problem if a combination of large and small vehicles is involved. An assessment of driver behavior, driver expectancy, traffic operations, and safety at MLA stop-controlled intersections is needed. Currently no information is available for intersection design guidelines that take traffic safety and driver behavior at MLAs under consideration. Appropriate intersection sight distance is further discussed in Chapter 2.

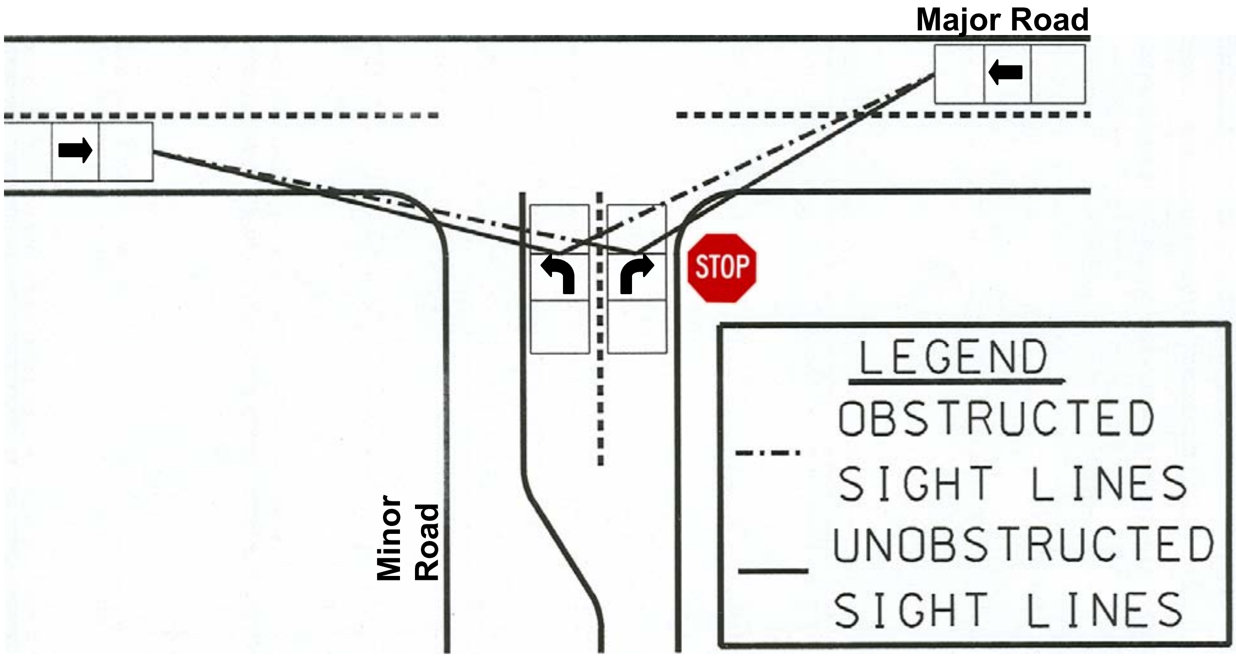


FIGURE 2 Sight Distance Obstructions at MLA Stop-Controlled Intersections Caused by Adjacent Stopped Vehicles

Detailed traffic safety records of multiple-lane approaches at two-way stop-controlled intersections is lacking, and past intersection safety research has largely ignored this category of intersections. The research available pertaining to two-way stop-controlled intersections almost exclusively assumes a single-lane approach (SLA) to the stop signs on the minor road.

Multiple-lane approaches controlled by stop signs are becoming increasingly common in Nebraska. Installation of MLAs occurs when a single approach lane can no longer adequately serve the minor road traffic volume, and a signal is unwarranted because Manual of Uniform Traffic Control Devices (MUTCD) warrants are not satisfied (7, FHWA, 2003). A common example of a location at which MLA stop-controlled intersections can occur in Nebraska is the rural intersection of two state or federal highways. Forty such intersections in Nebraska were available for study in this research. Additionally, such intersections are often located in suburban areas of Nebraska municipalities where the local-collector network of a residential development connects to an arterial roadway.

National Concern Over the MLA Issue
The first step in exploring the issue at hand was an investigation of various state transportation agency policies on the subject of MLA stop-controlled intersections to define a frame of reference for further study. A survey comprised of the following message was electronically transmitted to each of the 50 state transportation agencies in August of 2004 resulting in the responses summarized in TABLE 1.

> *"To whom it may concern:*
> *The Mid-America Transportation Center at the University of Nebraska-Lincoln is undertaking a research study on behalf of the Nebraska Department of Roads in the area of multiple-lane approaches to two-way stop-controlled intersections. As a portion of our preliminary research, we are surveying other state transportation departments for their policies on this matter and we would appreciate your input. Does your particular state express written policy with respect to multiple-lane approaches at stop signs and if so, could you fax a copy of your policy on the matter to XXX-XXX-XXXX?"*

The survey had a response rate of 20 percent. As is shown in TABLE 1, nearly all of the replying states have no formal policy on this subject. Pennsylvania's use of the MUTCD (7, FHWA, 2003) does not expressly allow or forbid MLA stop-controlled intersections, but rather skirts the issue by suggesting sign usage for intersections that already exist. Based on the survey results, 30 percent of responding transportation agencies across the country indicated a level of discomfort with using these types of intersection configurations.

TABLE 1 State Department of Transportation Responses to Email Survey

State Department of Transportation	**No Written Policy**	**Follows MUTCD**	**Dislikes**	**Discourages Use**
Arkansas	x			
Connecticut	x			
Idaho	x			X
Kentucky	x			
Maine	x		x	
Nebraska	x			
Ohio	x			
Pennsylvania		x		
Tennessee	x			
Wyoming	x		x	
Percentages	**90**	**10**	**20**	**10**

Poor intersection sight distance may result in increased user costs due to crashes resulting in property damage and injury to vehicle occupants. Large queues may pressure drivers at the front of the queue on a minor approach into accepting smaller than desired gaps, leading to possible unsafe behavior (8, Adebisi et al, 1989). While this issue is pertinent at all intersections, it is important to recognize its importance in this case, with the unique sight-distance obstruction conditions that occur at MLA sites.

Multiple-lane approaches are most likely suitable at locations that exhibit a heavy volume movement in one of the dual approach lanes and fairly light traffic volume in the adjacent lane. Lane volume may alternate in the morning, midday or evening peaks near residential neighborhoods, depending on the direction of trip attractions. MLA intersections in Nebraska most often consist of 3 approach legs or 4 approach legs with one approach having relatively very little traffic volume (therefore mimicking general traffic operations at 3-leg intersections).

Research Project Objective and Resulting Hypotheses

The objective of this research is to investigate driver safety and behavior at two-way stop-controlled MLA intersections. The reason for the investigation is to gain a better understanding of potential sight distance limitations due to side-by-side stopped vehicles at stop signs, as described earlier.

Safety Aspect of the Project

Hypotheses were developed to assist in the recognition and quantification of safety issues at MLA stop-controlled intersections. It is critical to determine if MLA intersections exhibit different average crash frequencies and different average crash rates than SLA stop-controlled intersections or signal-controlled intersections. Statistical analyses is used in this study to determine if MLA stop-controlled intersections are as safe as SLA stop-controlled intersections and signalized intersections. Shown below are the null and alternative hypotheses used in the statistical analysis.

Hypotheses 1 and 2: Crash Frequency

$\mathbf{H_{01}}$: $\mu_1 = \mu_2$
$\mathbf{H_{a1}}$: $\mu_1 \neq \mu_2$
$\mathbf{H_{02}}$: $\mu_1 = \mu_3$
$\mathbf{H_{a2}}$: $\mu_1 \neq \mu_3$

Hypotheses 3 and 4: Crash Rate

$\mathbf{H_{03}}$: $\mu_4 = \mu_5$
$\mathbf{H_{a3}}$: $\mu_4 \neq \mu_5$
$\mathbf{H_{04}}$: $\mu_4 = \mu_6$
$\mathbf{H_{a4}}$: $\mu_4 \neq \mu_6$

where:

μ_1 = 5-year mean crash frequency at MLA stop-controlled intersections,
μ_2 = 5-year mean crash frequency at SLA stop-controlled intersections,
μ_3 = 5-year mean crash frequency at signalized intersections,
μ_4 = 3-year mean crash rate at MLA stop-controlled intersections,
μ_5 = 3-year mean crash rate at SLA stop-controlled intersections, and
μ_6 = 3-year mean crash rate at signalized intersections.

Study Methodology

The methodology adopted for this research consists of several elements described briefly below.

Safety Aspect

- **Literature Review -** Previous research related to driver behavior and relevant intersection safety is summarized, including the methods used in data analysis.

- **Data Collection and Aggregation -** Crash data for 40 MLA stop-controlled intersections were available from the Nebraska Department of Roads (NDOR). These intersections vary in characteristics such as geometry, major road speed limit, and traffic volume. The characteristic that all intersections in this group share is that they have, or once had, distinctively striped multiple lanes on a stop-controlled approach. Of these 40 intersections, 4 are no longer MLA stop-controlled intersections. Relevant traffic authorities converted 3 locations to signal control, while one had one lane removed from the stop-controlled approach, returning it to a single-lane approach stop-controlled intersection (SLA). These 4 intersections have sufficient data for use in testing Hypotheses 1 and 2 by the method described in Chapter 3.

  A second data pool was necessary for testing of Hypotheses 3 and 4. For this purpose, crash rates and geometric characteristics for 54 intersections without MLA characteristics were used from a database from NDOR.

- **Safety Analysis -** Crash data from one intersection that was converted to a single-lane stop-controlled intersection are used to test Hypothesis 1, while data from three intersections that were signalized are used to test Hypothesis 2. Testing of Hypotheses 1 and 2 utilizes the Empirical Bayes Comparison-Group Method (9, Hauer, 1997). The Empirical Bayes method uses a large comparison group, in this case the remainder of the MLA control group intersections, to determine an estimate of the typical number of crashes at such intersections in a designated "before" period. This estimate was then used to project how many crashes would have occurred at the treated intersections had signalization or conversion to a single lane not occurred. By using these estimates in conjunction with the actual data, a measure of safety change is quantifiable.

  Crash frequency analysis will indicate whether signalization or single-lane conversion resulted in a safety change at this type of intersection. The results of Hauer's method yield indices of effectiveness, which may be converted to an estimate of the percent change in crashes that result from the treatment studied (in this case, conversion to a single-lane approach or signalization).

  For testing Hypotheses 3 and 4, the study sites were categorized into subgroups based on geometry by:

  - Number of intersection legs,
  - Number of through lanes on the major roadway, and
  - Posted speed on the major roadway.

The reason for categorizing the data into the above categories is that previous research shows these characteristics to affect intersection safety. Cribbins et al (10, Cribbins et al, 1967) positively correlated expressway speed limit to intersection safety as measured by crash rates. Harwood et al (11, Harwood et al, 1995) also found a positive correlation between number of intersection legs and crash frequency, as well as a similar correlation between intersection safety and number of through lanes on the major road. In the case of these previous research studies, a positive correlation means that, for example, as the number of intersection approach legs increase, intersection safety decreases, as measured either by crash rate or crash frequency.

Crash rate analysis will indicate whether MLA stop-controlled intersections have different average crash rates than other intersection types, testing Hypotheses 3 and 4. This portion of the overall analysis utilizes a 3-Factor Analysis of Variance table to conclude whether geometric factors such as number of approach lanes affect the crash rate at an intersection.

- **Conclusions and Recommendations -** Conclusions are drawn from the results of the safety analysis. The expected conclusions are that MLA stop-controlled intersections are not as safe as two-way stop-controlled intersections with single-lane approaches and intersections with signals. Based on the conclusions, recommendations are made regarding the use of two-way stop-controlled MLA intersections.

Driver Behavior Aspect

Many MLA intersections will remain in use or be built in the future to reduce driver delay regardless of the outcome of the safety studies outlined above, since these locations will not meet warrants for signalization and/or will be in remote areas of Nebraska where installation of a signal for operational purposes will have negative safety impacts for other reasons. Wide-throated SLA intersections that have been constructed to accommodate large trucks can also function as MLA intersections when two vehicles on the stopped approach are small, relative to the paved surfacing available to queue adjacent to major road. FIGURE 3 shows an example of such a “flared” intersection approach throat.

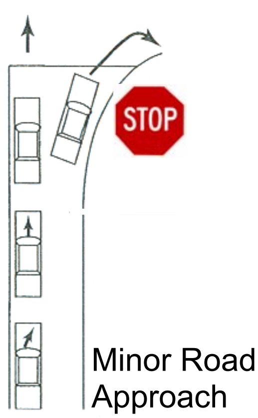


FIGURE 3 Illustration of a Flared Intersection Approach that Functions as an MLA-Type Intersection (12, Highway Capacity Manual, Exhibit 17-18, pg. 17-21)

Therefore, in addition to study of the safety of MLAs, it is necessary to study driver behavior at such locations to determine what both *a priori* and *ad hoc* driver expectancy lend to how the intersections perform. Any geometric recommendations that result from this part of the study must conform to existing driver expectations at these types of locations.

FIGURE 4 shows the hierarchy of movements at a two-way stop-controlled intersection. Traffic streams 13, 14, 15 and 16 refer to pedestrians, if they are a consideration. This study will not include consideration of pedestrians since those intersections under study did not exhibit significant if any pedestrian usage. According to these guidelines, if a left- and right-turning vehicle are stopped at the same time, the right-turning vehicle has priority over the left, since the driver only requires a suitable gap in traffic from the major road traffic approaching the intersection from the driver's left side.

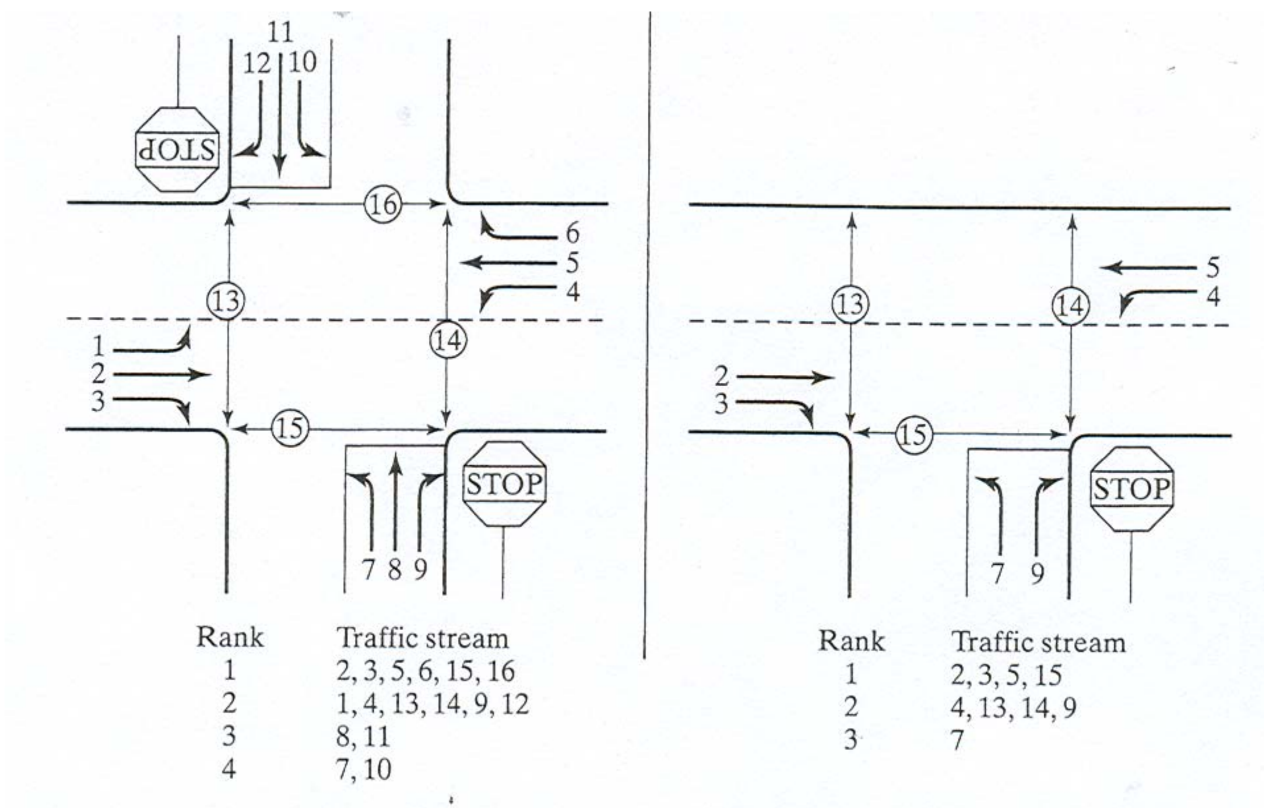


FIGURE 4 Priority of Vehicle and Pedestrian Movements at a 2-Way Stop-Controlled Intersection (12, Highway Capacity Manual, Exhibit 17-3, pg. 17-4)

Chapter 2
LITERATURE REVIEW

Intersection crashes comprise a large portion of total roadway crashes. According to the Federal Highway Administration (FHWA), 21 percent of the total fatalities on the nation's roadways occurred at intersections (1, FHWA, 2008). A possible cause for a number of intersection crashes may be sight distance obstructions that limit the ability of drivers to properly assess available gaps in oncoming traffic. A review of gap acceptance by drivers, sight distance at intersections, and research on driver behavior and safety improvement is presented in this chapter.

Gap Acceptance

Several researchers (3, Ashworth, 1968; 5, Hewitt, 1968; 4, Troutbeck, 1975; 6, Fitzpatrick, 1991) conducted preliminary work on gap acceptance and modeling of drivers' critical gap. Critical gap for a maneuver is often estimated empirically by examining gaps accepted and declined by drivers at intersections. Gap data is collected in different ways, sometimes by an observer standing by an intersection with a stopwatch.

Critical gap, or critical headway, is an important factor in determining intersection capacity. Headway is defined as the time between successive vehicles in a stream of traffic. Hansson et al (13, 1978) and Brilon et al (14, 2005) used critical gap to estimate a model for capacity and delay at unsignalized intersections. Brilon et al (14, 2005) applied their model specifically to two-way stop-controlled intersections and calibrated it empirically by using video footage of several intersections, while Hansson et al (13, 1978) originally estimated their model applied to signalized intersection application but later found that it applied reasonably to stop- and yield-controlled intersections, as well.

Capacity, used in conjunction with traffic volume, helps to determine the geometry and traffic control choice at an intersection. A generalized characteristic of the MLA stop-controlled intersections at 4-leg locations is that the MLA approach is comprised two lanes: usually one left-turn lane and one through lane that also serves right-turning traffic. There may also be a configuration with one left/through lane and a separate right turn lane. At 3-leg intersections, one lane would be assigned for left-turning vehicles and the other for right turners. While researching the need for installation of a left-turn bay at an intersection, Michalopulos (15, 1978) found that critical gaps for drivers facing one and two lanes of opposing traffic did not vary widely. Agent (16, 1983) reported left-turn lane installation warrants based on crash experience, traffic conflicts, traffic volumes and traffic control. Traffic conflicts relating to left turn movements are often evident when gaps in opposing traffic lower capacity at an intersection to a point that queues form at stop signs.

Agent's study was applicable to signalized and unsignalized intersections, while Lin and Machamehl (17, 1983) conducted a similar study, which was only applicable to signalized intersections. This study used left-turn capacity at signalized intersections to devise a warrant for a protected left-turn phase in the signal timing. At signalized intersections without a protected left-turn phase, the number and size of opposing gaps as drivers choose them to perform the left-turn maneuver determine the left-turn capacity. The scope of work covering the topic of gap acceptance is broad, and these references comprise a framework of the applicable research.

Intersection Sight Distance

Intersection sight distance (ISD) is of concern for every roadway design engineer, as lack of proper ISD can lead to unsafe driving conditions. The American Association of State and Highway Transportation Officials (AASHTO) has detailed a sight triangle that is relevant at a stop-controlled intersection (18, NCHRP, 1986). Intersection sight triangles are imaginary lines formed by a driver's sight line to an object, usually an approaching vehicle. The driver's sight line forms the hypotenuse, while each leg is formed by perpendicular distances from the driver's eye to the center of the major roadway driving lane and driver's eye to the oncoming vehicle, as shown in FIGURE 5.

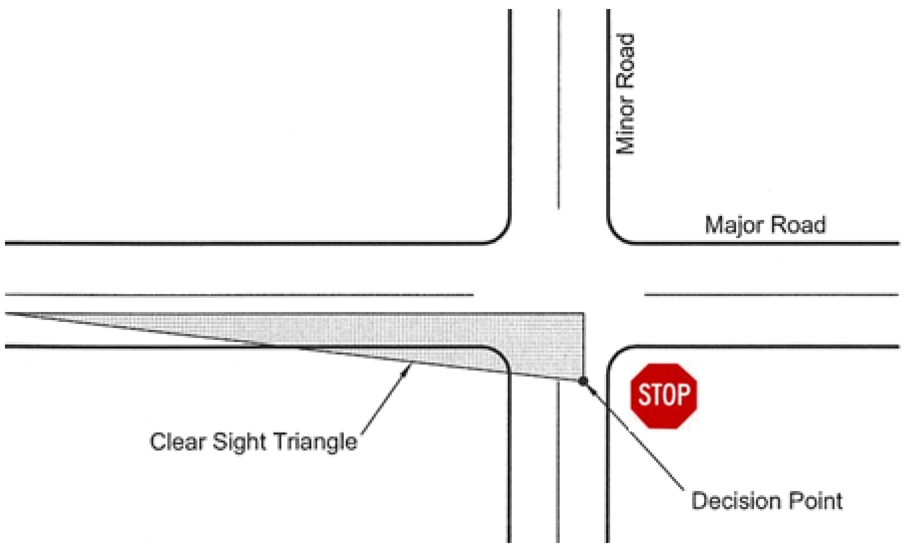


FIGURE 5 Example of Departure Sight Triangle (19, FHWA, 2004)

The relevant sight triangle when a driver is departing after coming to a stop at an intersection with two-way stop-control is called a departure sight triangle. When two vehicles are stopped next to each other at an MLA stop-controlled intersection, the departure sight triangle can be obstructed. Khattak and Gopalakrishna (20, 2003) found that rectifying sight distance obstructions could improve safety at intersections, at least concerning older drivers with slower reaction times.

Research on Safety Improvements at Intersections

There are several literary works (21, Hauer et al, 1986; 22, Hauer et al, 1988; 9, Hauer, 1997; 23, Neudorff et al, 1998; 24, Storsteen, 1999; 25, Yuan et al, 2001) presented on the topic of measuring safety improvements at intersections after some physical change (treatment) for improving safety. Several such works were reviewed that led to the selection of the most appropriate method to be used for study of MLA intersections. The fact that Hauer authors three of these works (21, Hauer et al, 1986; 22, Hauer et al, 1988; 9, Hauer, 1997) in part or in whole is not coincidental, as much of the theory and methodological developments in highway safety have been reported by him.

An example of a recent attempt to quantify intersection safety in an "assembly-line" fashion was in a report published by the South Dakota Department of Transportation entitled "Identification of Abnormal Accident Patterns at Intersections" (24, Storsteen, 1999). This work classified all of South Dakota's intersections into categories based on their geometric characteristics and traffic volumes. The historical crash data for each intersection class was then summed into an expected value analysis (EVA) table, in which crashes were divided into subtypes by factors such as type, severity, environmental conditions, time, and the involvement of such mitigating factors as alcohol or drugs. These EVA tables were then used to predict future crashes at an intersection as well as analyze whether an intersection was performing abnormally. Although this seemed an intuitive approach, its main hindrance was the sheer volume of data and labor required to create the EVA tables.

There are essentially two other methods used in previous work to predict the safety of an intersection. The first method involves creating a model using different variables to predict what future crash frequencies may be at an intersection. The variables used typically classify the intersection in some manner, divide crash data into groups by collision type, or include in the model other factors as deemed necessary by the researcher.

One such model, put forth by Hauer et al. (21, 1986), estimated models based on a more specific scale of crash type. In addition to reducing the inherent ambiguity raised by classifying crashes on the normal scale (rear-end, angle, turning movement, etc.), this allowed researchers to estimate very specific models based on the traffic flows contributing to the crash types. This research concluded that models of this type were more accurate than models that attempt to predict a certain type of crash based on Annual Average Daily Traffic (AADT) of an intersection or some equivalent measure of total traffic. It is desirable, according to Hauer et al (1986), that specific crash types be related only to the traffic flows that are involved in creating the crash.

Neudorff, Persaud and Nguyen (23, Neudorff et al, 1998) developed two levels of such a model. In the first level, models were estimated to account for intersection geometry, crash severity and type, time period, and an environmental class factor such as suburban or rural. The second level of model predicted a more specific type of crash, breaking the crash types down into 12 multi-vehicle types and three single-vehicle types.

The second method of predicting safety improvement at an intersection is a variant of a before-after study at an intersection. Hauer (9, 1997) showed conclusively using empirical data that a simple before-after study does not correctly predict crashes in the after period at an intersection. A simple before-after study is a straightforward comparison of before and after crashes reported at an intersection to which a safety treatment was applied. Instead, several modifications must be made to this method to improve its reliability. The first such improvement, introduced by Hauer in 1988 (22, Hauer, 1988) and later detailed in 1997 (9, Hauer, 1997), is a correction to the before period crashes, which removes regression-to-mean (RTM) bias. RTM bias occurs if before period crashes on an intersection that underwent some safety treatment are used as a predictor of typical before period crashes at an intersection of that type. The safety treatment would likely not have been applied if crashes on that intersection during the before period had not been abnormally high. Thus, using before period crashes on the treated intersection as typical values will result in an overestimation of the normal number of crashes in the before period at an intersection of this type. Conducting the analysis using this overestimated value will, in turn, result in overestimation of the safety benefit of the treatment.

The correction for RTM bias is based on Bayes' theorem for prediction of random events. Applying the correction, detailed in Chapter 3, will allow for better prediction of the "after" period crashes. This is especially important when examining the effect of a perceived safety improvement at an intersection, as is the case in this study. The Empirical Bayes method has already been used in similar situations with good results. Yuan et al. (25, 2001) applied the method in a like manner to a project investigating the safety effects of realigning intersection approaches in rural highways. The results of that study found that realigning intersections to reduce skew improved safety by lowering crash frequency. Other treatments investigated in the study that did not offer safety improvement were signalization or the addition of a left-turn bay.

Summary

As detailed previously, there are resources available giving methods of measuring safety characteristics of intersections in general. There is, however, no available research pertaining specifically to MLA two-way stop-controlled intersections, despite research on gap acceptance and sight distance that are helpful in understanding operational issues at MLA two-way stop-controlled intersections. In this literature review, gap acceptance and sight distance related literature was reviewed, as well as a summary of the different methods of measuring and reporting intersection safety, concluding with the choice of the method that will be used in the safety analysis.

The review of gap acceptance literature established the importance of the critical gap in determining the capacity of an intersection which is then used in conjunction with anticipated traffic volumes to determine design characteristics of the intersection; including geometry and traffic control.

The reviewed sight distance related literature established the importance of adequate sight distance in creating a safe environment for drivers to navigate an intersection. At MLA stop-controlled intersections, clear sight triangles may not always be available, which may result in unsafe driver behavior.

The review of literature related to measuring and reporting safety explored different methods that have been used in the past to quantify the change in safety resulting from a treatment. This literature involved modeling approaches as well as simple and Empirical Bayes before-after studies. The result of this literature review was the selection of the method that is used to test Hypotheses 1 and 2 in Chapter 3.

Chapter 3
STUDY DESIGN METHODOLOGY

Before-After Comparison Group Studies

The methodology selected for crash frequency analysis in this study is from Chapter 11 of Hauer's book *Observational Before-After Studies in Road Safety* (9, 1997). TABLE 2 shows a summary of the notation of each commonly used variable along with its definition.

TABLE 2 Variable Notation Used for Safety Analysis

Variable	Description
κ, K	Before period expected (κ) and observed (K) crashes in treatment group
λ, L	After period expected (λ) and observed (L) crashes in treatment group
μ, M	Before period expected (μ) and observed (M) crashes in comparison group
ν, N	After period expected (ν) and observed (N) crashes in comparison group
π	Expected crashes in after period on treatment group, had it not been applied
δ	Reduction in after period crashes resulting from treatment (π-λ)
θ	Index of effectiveness (λ/π)

The reportable result of the Empirical Bayes before-after analysis is θ, which shows how effective treatment was in improving safety. Typically, the comparison group will mirror the treatment group in every possible way, in order to lend validity to this method of analysis.

The first step in this analysis is finding a reliable estimate of κ, denoted by $\hat{\kappa}$. In a simple before-after study, a researcher will typically use the observed crashes (K) as an estimate of safety in the before time period. Because of RTM bias, this results in using a higher value for estimation of before period crashes. Thus, simple mean crash counts in the before period are not a good estimate of the average safety performance of an intersection that has exhibited a relatively worse safety record in the recent past. It is desirable to remove RTM bias by adjusting κ based on the comparison group.

The number of crashes in the before period on the comparison groups was averaged for each individual class of crash, as well as the total. This expected average value is termed E(κ). According to Hauer (22, 1997, p. 197), the value κ also has a variance, estimated by EQUATION 1. The average number of observed crashes in the before period on the treatment intersection is still termed K. Equation 2 (22, Hauer, 1997, p. 189) and the correction factor from Equation 3 (22, Hauer, 1997, p. 189) derive a value of E(κ|K). This value substitutes for κ in subsequent formulas.

$$Var(\kappa) = s^2 - \bar{K} \qquad \text{(EQUATION 1)}$$

$$E(\kappa \mid K) = \alpha E(\kappa) + (1-\alpha)K \qquad \text{(EQUATION 2)}$$

$$\alpha = \frac{1}{1 + \frac{Var(\kappa)}{E(\kappa)}} \qquad \text{(EQUATION 3)}$$

where:

Var (κ)	= Variance of expected before period crashes,
s^2	= Sample variance of before period reported crashes,
$\bar{K}$	= Sample mean of before period reported crashes,
E (κ|K)	= Expected value of κ (before period crashes), given that the intersection experienced K crashes,
α	= Correction factor, and
E(κ)	= Expected value of before period crashes, estimated by K.

Now that the safety in the before period is estimated without RTM bias, the analysis procedure focuses on defining safety in the after period. Hauer (22, 1997) elected to use L as an estimate of λ (the safety in the after period with treatment). The variance of λ equals L, since λ is assumed to be Poisson distributed, and the mean and variance of the Poisson distribution are equal. The more important parameter to define here is π, which provides a way to measure the safety change due to the treatment. EQUATION 4 (22, Hauer, 1997, derived from p. 215) shows the calculation for π.

$$\pi = r_T r_{tf} \kappa \qquad \text{(EQUATION 4)}$$

where:

π	= Expected crashes in the after period on treatment group, had treatment not been applied,
r_T	= Ratio of expected crashes for the treatment group,
r_{tf}	= Traffic correction factor, and
κ	= Expected before period crashes in treatment group.

This is where the emphasis on the comparison group is applicable. The first parameter used to raise κ to π is r_T. This parameter, calculated using Equation 5 (22, Hauer, 1997, p. 121), is the ratio of after period crashes to before period crashes on the comparison group.

$$r_T = \frac{\frac{N}{M}}{1 + \frac{1}{M}} \qquad \text{(EQUATION 5)}$$

where:

N	= Observed after period crashes in comparison group, and
M	= Observed before period crashes in comparison group.

This ratio is approximately equal to the ratio of after period crashes to before period crashes in the treatment group, and thus is usable to project what the safety would have been in the after period without treatment.

The second parameter used in EQUATION 4, r_{tf}, is the adjustment factor for traffic (22, Hauer, 1997, p.101). This is calculated from average annual daily traffic (AADT) in the before and after period. It is important to note that Hauer (22, 1997, pp.101, 121) also puts forth formulae for the variances of each of these parameters that are obtainable from the text. In addition, the portion of the variance of π that has to do with r_{tf} is not fixed, as the values used to calculate r_{tf} are the exact values taken from data, and therefore exhibit no variance.

The objective of this methodology is to gain measurable and reportable results. The next parameter to calculate is δ, using EQUATION 6 (22, Hauer, 1997, p. 62).

$$\delta = \pi - \lambda \qquad \text{(EQUATION 6)}$$

where:

- δ = Net safety change,
- π = Expected crashes in the after period on treatment group had treatment not been applied, and
- λ = Expected after period crashes in treatment group.

This parameter gives an estimate of the change in safety due to treatment. However, since it does not relate this improvement to the magnitude of either value, it is not as useful as θ in describing the results of this analysis, which is the index of effectiveness and is calculated using EQUATION 7. A value of θ less than one, for example, shows that safety improved after application of the treatment, while a θ value greater than one indicates that safety decreased after application of the treatment. A θ value of exactly one indicates no change in safety.

$$\theta = \frac{\frac{\lambda}{\pi}}{1 + \frac{\operatorname{var}(\pi)}{\pi^2}} \qquad \text{(EQUATION 7)}$$

Perhaps an even clearer result of this method is the percent change in crashes, which EQUATION 8 estimates. A negative value obtained from this equation indicates adverse effects on safety, as there would have been a net gain in crashes.

$$\textit{Percent Change} = 100 * (1 - \theta) \qquad \text{(EQUATION 8)}$$

where:

- θ = Index of treatment effectiveness,
- λ = Expected after period crashes in treatment group,
- π = Expected crashes in the after period on treatment group, had treatment not been applied,
- *Var(π)* = Variance of expected before period crashes in treatment group, and
- *Percent Change* = Percent change in safety due to treatment

Crash Rate Comparison Study
The technique used for testing Hypotheses 3 and 4 was 3-factor Analysis of Variance (ANOVA). Intersection crash rates were entered into Statistical Package for Social Sciences (26, SPSS) software with variables that separated the rates into categories by intersection type, number of approach legs, number of through lanes on the major roadway, and posted speed limit on the major roadway. Intersection type was categorized into the three groups below:

- MLA stop-controlled intersections,
- SLA stop-controlled intersections, and
- Signal-controlled intersections.

The variable "Number of Approach Legs" took a value of either three or four. The variable "Number of Through Lanes on the Major Roadway" took values of either two or four. To simplify analysis, the variable posted speed limit was categorized into three groups, shown below.

- 45 miles per hour or lower,
- 50-55 miles per hour, and
- 60 miles per hour or higher.

Due to the relatively small intersection pool of 94 (in comparison to similar studies by Hauer), the use of only three of the four factors increased the power of the test. In addition, the interactions among factors in a four-factor ANOVA are difficult to interpret. Since intersection type is the factor of interest for this study, it is included automatically. Research shows that two other factors have been shown to be relevant to this problem (10, Cribbins et al, 1967; 11, Harwood et al, 1995). These are the number of through lanes on the major roadway and the number of intersection legs. In the interest of completeness, all three available combinations of factors will be analyzed using 3-factor ANOVA. The three factors used in the ANOVA presented in the results section in Chapter 5 are:

- intersection type,
- posted speed limit on the major roadway, and
- number of intersection legs.

The 3-factor ANOVA first tests the significance of the three factors chosen to find if they have significance at the 95 percent confidence level. If a factor is significant, then one or more of the mean crash rates is not identical across that factor. Post-hoc tests such as Tukey's Test or Dunnett's C Test can find which means are different and the magnitude of the difference between the factors. The idea behind using two different post-hoc tests is that Tukey's Test assumes that the means have equal variances, while Dunnett's C Test does not assume equal variances. The results of this analysis, as well as those of the preceding section, are in Chapter 5.

Chapter 4
DATA COLLECTION METHODOLOGY AND STUDY INTERSECTIONS

Two sets of data were collected for use in this study. The first data set used for testing Hypotheses 1 and 2 was comprised of intersections that are or once were MLA stop-controlled intersections. The second set was comprised of a variety of intersections that are not MLA stop-controlled, which was used to test Hypotheses 3 and 4. Crash data for 40 intersections were collected from safety archives in the Traffic Division of NDOR. The selection of these 40 intersections was based upon the presence of multiple-lane approaches (either striped for two separate lanes or exhibiting wide enough intersection throats for frequent use as a multiple-lane approach). Collected data consisted of crash summary reports as well as individual crash reports covering intersection operation from 1989-2004. The data were summarized by crash types and severities. Also, crash rates for 54 randomly selected single-lane approach intersections, both signalized and stop-controlled, were collected for testing Hypotheses 3 and 4.

Three intersections in the MLA sample population currently have signals providing traffic control. These intersections came under signal control in 1994, 1997, and 1999. For these three sites, 11 years of crash data for each intersection was requested, encompassing five years prior and five years after the signalization year, in addition to the year of signalization. This was for conducting a before-after comparison group study to analyze the effect of signalization as a safety treatment at these intersections. The comparison group used for this study consisted of the intersections from the MLA sample population that share geometric similarities to the three converted intersections.

One intersection in the MLA sample population chosen by NDOR was converted back to a single-lane approach due to safety concerns in the year 2000. For this site, a similar study to the comparison group study explained previously was conducted to determine if this treatment improved safety at the intersection.

To conduct the studies described in the introductory paragraphs of this project report, large quantities of crash data for 40 intersections were gathered for the years from 1989 to 2004. The rationale behind data requests to encompass a large number of intersections as well as a long period is to reduce the sampling error inherent in small sample populations. Therefore, the largest available number of intersections was requested from NDOR for use in this study. TABLE 3 presents a summary of the intersection data.

TABLE 3 Intersection Characteristics Summary

Intersection Legs	Intersection Type	Count
4-legged	MLA, 2 Through Lanes on Major Road	16
	MLA, 4 Through Lanes on Major Road	13
3-legged	MLA, 2 Through Lanes on Major Road	9
	MLA, 4 Through Lanes on Major Road	2
	Subtotal	**40**
4-legged	Single lane stop-controlled	29
	Single lane signalized	13
3-legged	Single lane stop-controlled	12
	Single lane signalized	0
	Subtotal	**54**
	Total	**94**

Before-After Comparison Group Studies

Data collected for the before and after comparison study portion of this project consisted of eleven years of crash data for 40 intersections including three now signalized intersections and one intersection that was converted to single-lane approach. For each of those 4 intersections, equal length before and after time periods of five years was desirable, while data for the year of the traffic control or lane change was discounted since the exact date of the change was not available. In some cases, the before and after time period varied slightly due to available data, but at least four years were available for each time period, and sometimes as many as eight were available. The differing time periods do not present a problem to the method of analysis used.

TABLE 4 lists crash details of the treatment intersections. Since study intersections 2, 3, and 4 have similar geometry, the same pool of intersections was usable for comparison purposes. The data were classified as either injury or PDO and as rear end, head on, side swipe, right angle, or turning movement.

TABLE 4 Before-After Treatment Intersection Details

No.	Intersection	Legs	Treatment Year	Location	Total Before Period Crashes	Total After Period Crashes
1	US HWY 6 & 56th ST	3	1999	Lincoln	36	58
2	US HWY 6 & NE HWY 10	4	1994	Minden	22	12
3	US HWY 275 & NE HWY 24	4	1997	Norfolk	20	32
4	US HWY 81 & US HWY 136	4	2000	Hebron	15	3

For the purpose of comparison groups, data from 36 multiple-lane-approach stop-control intersections were gathered for the time period spanning 1989 through

2004, which allowed for a minimum of five years in the before and after periods. These intersections are summarized in TABLE 5.

TABLE 5 Before-After Comparison Intersections

Number of Intersection Legs	Number of Multiple-Lane Approach Intersections Studied
3	10
4	25

The data collected from NDOR for the before-after studies was in the form of crash reports. A query sheet obtained from NDOR for each intersection listed each crash at that location chronologically through the desired time period. These query sheets were aggregated into a spreadsheet. TABLE 6 shows a sample record of the aggregate data for one intersection. The data were divided according to year and crash type.

TABLE 6 Sample Intersection Record

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
W N-92 & US-26																
Fatal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Injury	2	0	0	0	0	0	0	0	0	0	0	3	1	0	1	0
PDO/N-R	1	2	1	0	1	0	0	0	0	1	1	0	1	0	0	0
Total	**3**	**2**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**3**	**2**	**0**	**1**	**0**
Rear End	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Sideswipe	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Angle	2	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0
Turning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Certain types of crashes were not common enough to complete a meaningful analysis. Fatal crashes, though tragic, are not common enough to provide accurate results using the Empirical Bayes method of analysis, so they were removed from investigation. In addition, for the three intersections that are now signalized, fatal crashes were unavailable from the data set, making analysis of fatal crashes impossible.

An aggregation of data consisted of the combination of PDO and non-reportable (N-R) crashes into one category. Non-reportable crashes in Nebraska are those crashes reported to the police that result in no injuries and property damage less than $1,000 (27, NDOR, 2005). Crash frequency data for MLA stop-controlled intersections and crash rates for the second pool of intersections are included in Appendices C and D, respectively.

Crash Rate Comparison Study

As discussed in Chapter 3, the analysis approach for testing Hypotheses 3 and 4 was a series of statistical analyses applied to the entire pool of 36 available MLA stop-controlled intersections to investigate whether intersections of this type have differences in safety from single-lane approach stop-controlled intersections or signalized intersections. For this portion of the research, an additional pool of control data was necessary. NDOR personnel collected a pool of 54 intersections from across the state of Nebraska. Safety data for these intersections was in the form of 3-year average crash rates, covering the years 2002 to 2004. This matched the crash rates calculated for the MLA stop-controlled intersections

The second pool of intersections came from a new database currently under development at the NDOR, and was the only one made available to the researchers at the time of study. Of these, 41 were under stop-control and 13 were under signal-control. TABLE 3 provides a summary of these intersections.

Descriptive statistics were calculated to further describe the intersection categories. TABLES 7, 8, and 9 show these statistics for each group of intersections used in the mean crash rate analysis. In each table, the column labeled **N** is the number of intersections that fit under each category. Minimum, maximum, mean, and standard deviation statistics of average crash rate over three years are shown in each table.

TABLE 7 Descriptive Statistics for MLA Data Mean Crash Rates

Category	N	Approach Legs	Through Lanes	Posted Speed Limit	Minimum	Maximum	Mean	Standard Deviation
1	9	3	2	≥60	0.00	1.4	0.37	0.44
2	9	3	2	N/A	0.00	1.4	0.37	0.44
3	2	3	4	≤45	0.10	0.46	0.28	0.25
4	2	3	4	N/A	0.10	0.46	0.28	0.25
5	11	3	2 or 4	N/A	0.00	1.4	0.35	0.40
6	4	4	2	≤45	0.00	0.57	0.30	0.27
7	1	4	2	50-55	0.16	0.16	0.16	0.00
8	11	4	2	≥60	0.00	1.9	0.48	0.56
9	16	4	2	N/A	0.00	1.9	0.41	0.48
10	1	4	4	≤45	0.25	0.25	0.25	0.00
11	2	4	4	50-55	0.00	0.44	0.22	0.31
12	11	4	4	≥60	0.00	1.0	0.48	0.36
13	14	4	4	N/A	0.00	1.0	0.43	0.34
14	30	4	2 or 4	N/A	0.00	1.9	0.42	0.42

TABLES 8 and 9 are similar summaries of the stop-controlled and signal-controlled comparison pools, respectively.

TABLE 8 Descriptive Statistics for Stop-Controlled Comparison Data

Category	N	Approach Legs	Through Lanes	Posted Speed Limit	Minimum	Maximum	Mean	Standard Deviation
1	1	3	2	≤45	0.00	0.00	0.00	0.00
2	4	3	2	50-55	0.00	0.66	0.26	0.32
3	6	3	2	≥60	0.00	0.38	0.11	0.17
4	11	3	2	N/A	0.00	0.66	0.15	0.23
5	1	3	4	≤45	0.19	0.19	0.19	0.00
6	0	3	4	50-55	N/A	N/A	N/A	N/A
7	1	3	4	≥60	0.09	0.09	0.09	0.00
8	2	3	4	N/A	0.09	0.19	0.14	0.07
9	13	3	2 or 4	N/A	0.00	0.66	0.15	0.21
10	3	4	2	≤45	0.57	1.3	0.84	0.41
11	2	4	2	50-55	2.41	4.2	3.3	1.3
12	10	4	2	≥60	0.00	0.92	0.22	0.37
13	15	4	2	N/A	0.00	4.2	0.76	1.2
14	1	4	4	≤45	0.52	0.52	0.52	0.00
15	1	4	4	50-55	0.79	0.79	0.79	0.00
16	11	4	4	≥60	0.00	0.95	0.18	0.28
17	13	4	4	N/A	0.00	0.95	0.26	0.32
18	28	4	2 or 4	N/A	0.00	4.2	0.53	0.91

TABLE 9 Descriptive Statistics for Signal-Controlled Comparison Data

Category	N	Approach Legs	Through Lanes	Posted Speed Limit	Minimum	Maximum	Mean	Standard Deviation
1	4	4	2	N/A	0.20	0.89	0.54	0.28
2	9	4	4	N/A	0.18	2.0	1.0	0.67
3	13	4	2 or 4	N/A	0.18	2.0	0.89	0.62

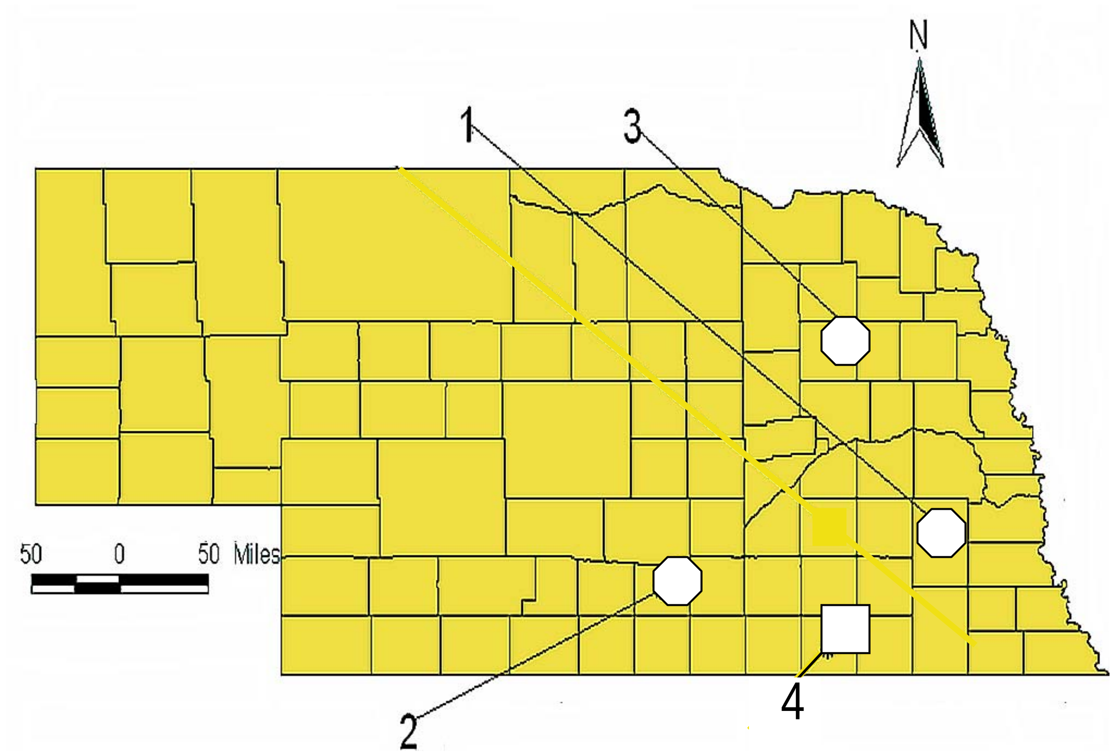
Although the total comparison population is 54, some of the sample categories are very small, having only one or two intersections in them. Comparison populations comprised of only one or two intersections are generally not effective tools in statistical analysis.

The data pool for the crash rate analysis consists of two parts. First, three-year crash rates were calculated for each multiple-approach-lane intersection in the original group. These rates were compiled in a database, and then transferred to SPSS statistical software (26). The comparison pool data, once aggregated into spreadsheet form and sorted according to TABLE 3, were also entered into SPSS for ease of analysis.

The study sites for this research are comprised of a wide variety of intersections. Of course, each intersection has the shared characteristics of being two-way stop-controlled and of having approaches to the stop signs that exhibit more than one lane. All 40 of the intersections used for the sample population of MLA stop-controlled intersections are in the state of Nebraska, and are scattered across the state. A majority of the sites are rural intersections of state and federal highways. A complete list as well as some basic information such as location, AADT, posted speed limit, and geometry of each of the MLA intersection sites can be found in Appendix B, but the 4 intersections that were investigated in the before-and-after comparison group studies will be detailed in this section. TABLE 10 lists the name and location of each intersection, while FIGURE 6 shows the location of these intersections on a Nebraska state map.

TABLE 10 Before-After Comparison Study Intersections

Intersection Number	Intersection	Location
1	US HWY 6 & 56th St	Lincoln
2	US HWY 6 & Nebraska HWY 10	Minden
3	US HWY 275 & Nebraska HWY 24	Norfolk
4	US HWY 81 & US HWY 136	Hebron



Map Symbol	□	⯃
Treatment	Lane Removal	Signalization

FIGURE 6 Study Intersection Locations

Intersection 1, shown in FIGURE 7, is the intersection of US Highway 6 and 56th Street in Lincoln, Nebraska. At this location, US Highway 77 is also known as 56th St within the community of Lincoln. Since US Highway 77 and US Highway 6 are two major routes used for entering and exiting the northeast portion of Lincoln from Interstate 80, this intersection receives a relatively large traffic volume of 10,000 vehicles per day on average. This intersection was stop-controlled until 1999, when it was signalized by the City of Lincoln Public Works and Utilities Department. This intersection was used as part of the before-after comparison group study on signalization as a treatment to improve safety at MLA stop-controlled intersections.

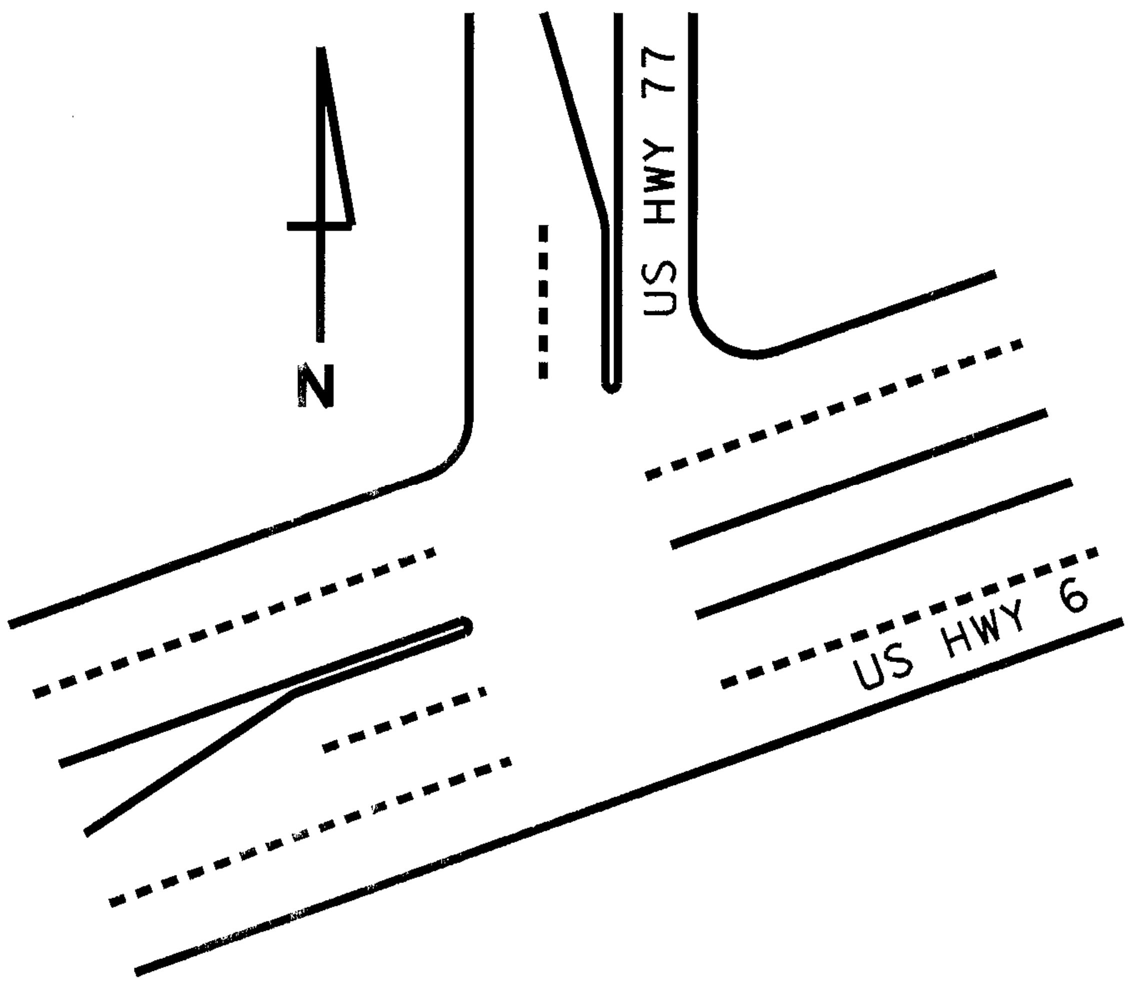


FIGURE 7 US Highway 6 & US-77/56th St, Intersection 1

Intersection 2, also investigated using the Empirical Bayes method is the intersection of US Highway 6 and Nebraska Highway 10 in Minden, a town in central Nebraska with a population of approximately 3,000. This intersection represents the main intersection in the city of Minden, and experiences an AADT of approximately 6,000 vehicles per day. In FIGURE 8, Nebraska Highway 10 runs north-south and US Highway 6 runs east-west. This intersection, which was signalized in 1994, was used as part of the before-after comparison group study on signalization as a treatment to improve safety at MLA stop-controlled intersections.

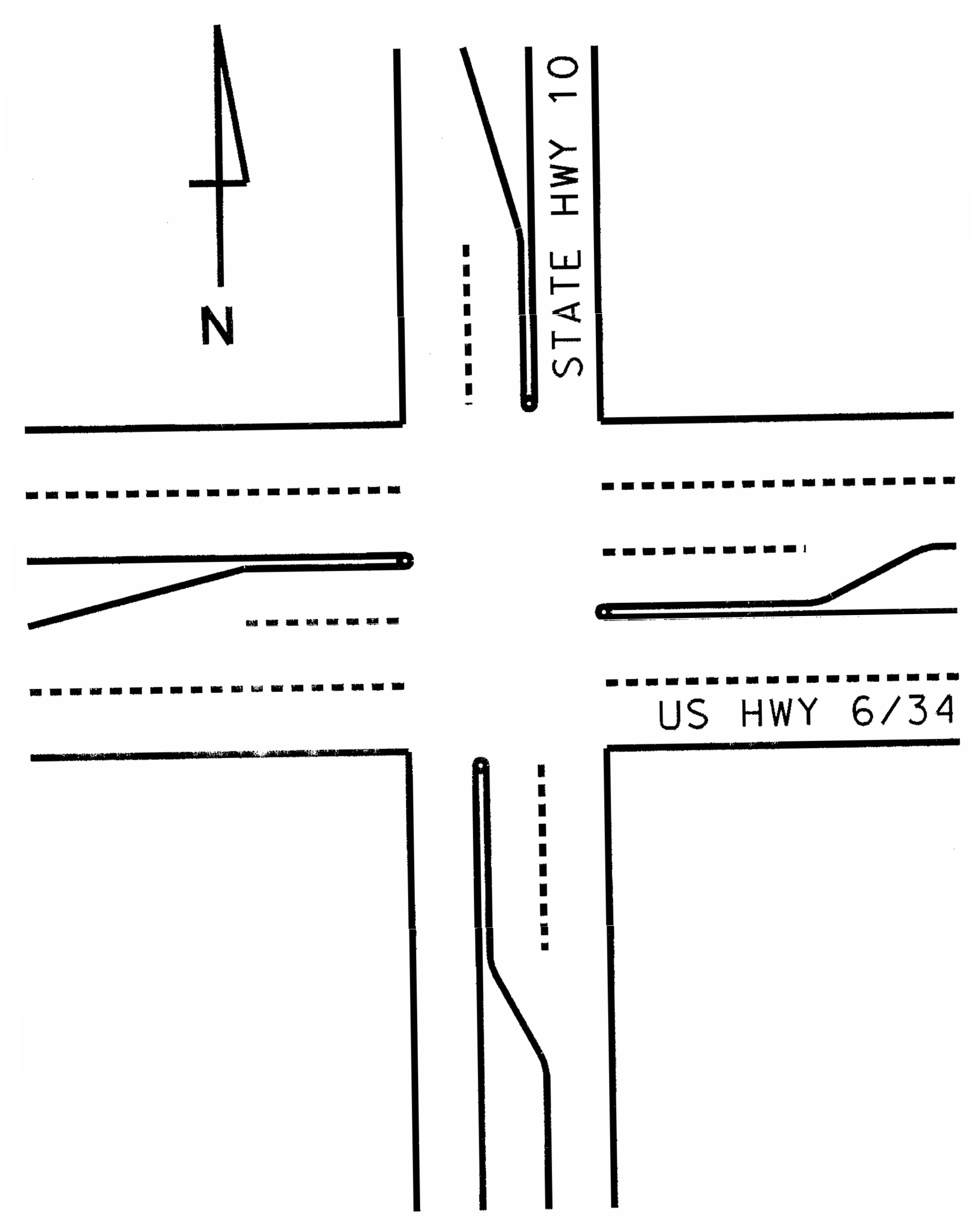


FIGURE 8 US Highway 6 & Nebraska Highway 10, Intersection 2

Intersection 3, the intersection of US Highway 275 and Nebraska Highway 24, lies on the eastern edge of Norfolk, a city with population approximately 24,000 in northeastern Nebraska. This intersection experiences an AADT of 6,500 vehicles per day and was signalized in 1997. In FIGURE 9, US Highway 275 runs east-west and Nebraska Highway 24 runs north-south. This intersection was used as part of the before-after comparison group study on signalization as a treatment to improve safety at MLA stop-controlled intersections.

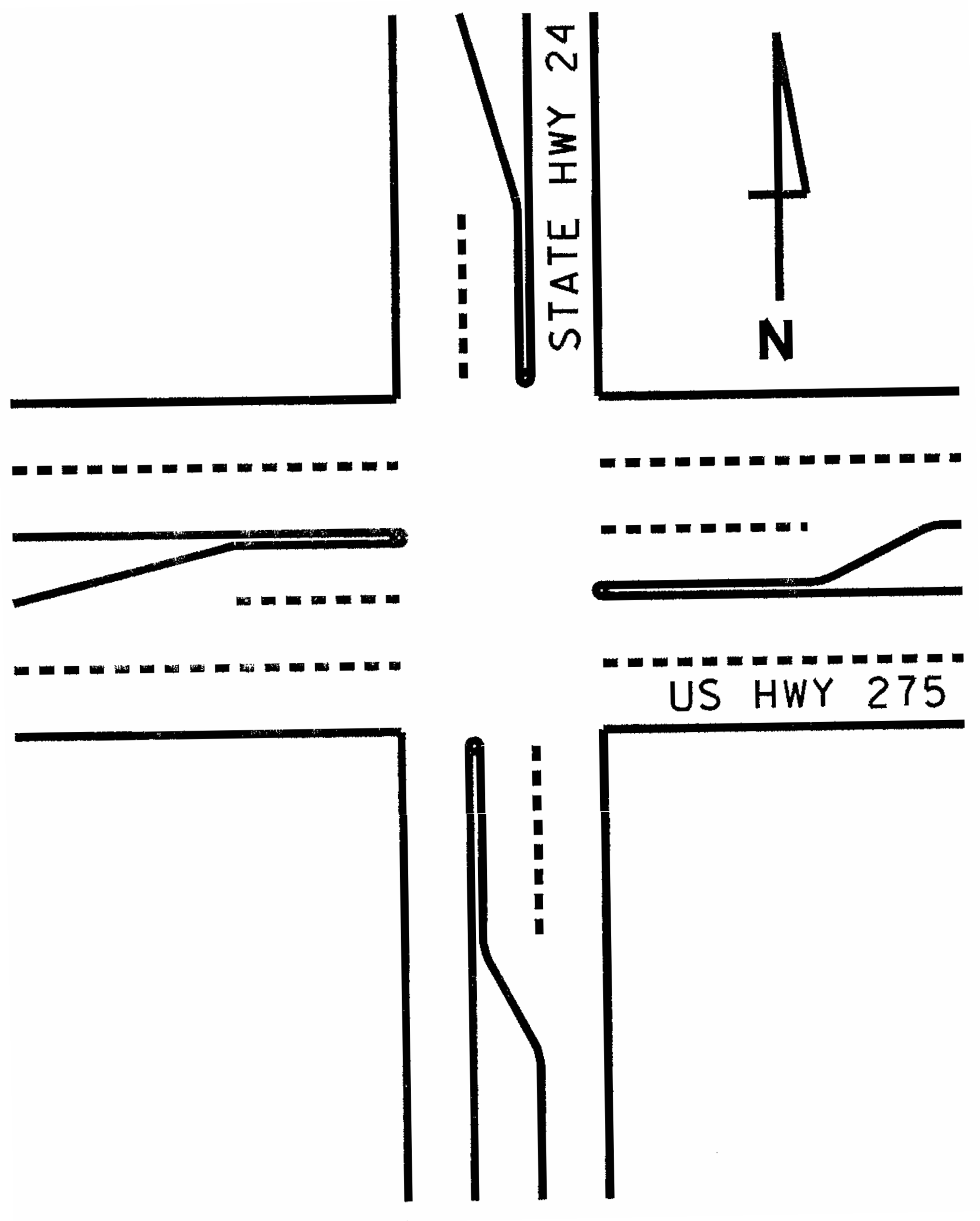


FIGURE 9 US Highway 275 & Nebraska Highway 24, Intersection 3

The intersection of US Highway 81 and US Highway 136, shown in FIGURE 10, is located in a rural area near the town of Hebron (population 1,500) in south-central Nebraska. The intersection experiences an AADT of 2,700 vehicles per day. Following a fatal crash involving a teen-aged girl, the left-turn lane on US Highway 136 was removed in 2000 to change this intersection to single lane intersection with two-way stop-control. This intersection was used as part of the before-after comparison group study investigating lane removal as a treatment to improve safety at MLA stop-controlled intersections.

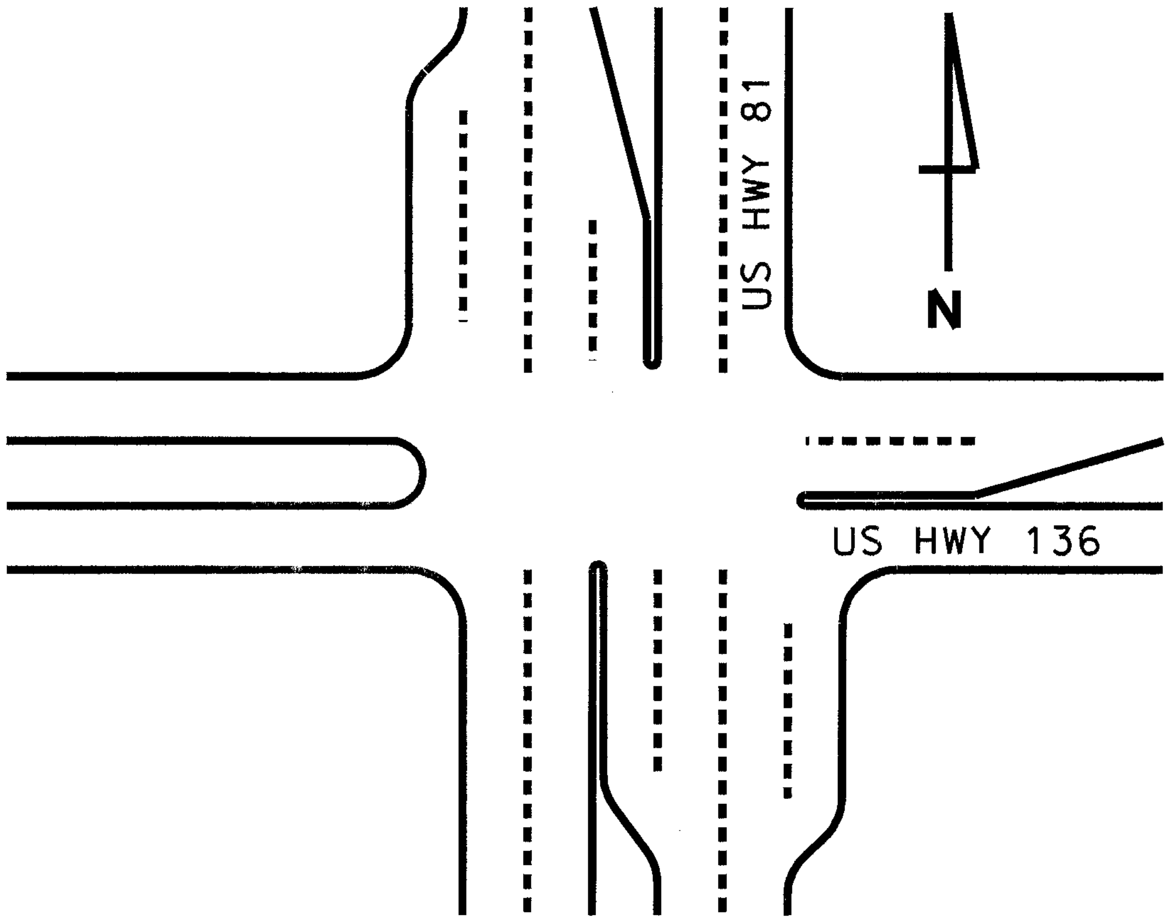


FIGURE 10 US Highway 81 & US Highway 136, Intersection 4

Chapter 5
RESULTS AND INTERPRETATION

Before-After Comparison Group Studies

The reportable results for this section of the research consist mainly of the values of the index of effectiveness and the percentage reduction in crashes derived from it. TABLES 11 through 14 show the results of the analysis conducted to test Hypotheses 1 and 2. Intersections 1 through 3 now have signal control, while Intersection 4 is now SLA stop-controlled. In the tables, $\hat{\kappa}$ is the estimate of the average before period crashes on the treatment group found through the analyses. The variance of $\hat{\kappa}$, denoted by var($\hat{\kappa}$) has an ideal value of zero. Theta (θ) is the index of effectiveness, with values ranging from zero to 1.55. As a reminder, values of θ less than one indicate an improvement in safety, a value of one indicates no change in safety, and values greater than one indicate deterioration of safety.

The variables K, L, M, and N are all actual averages of reported crashes at the intersections. K is the five-year average of the before period crashes on the treatment group, and L is the five-year average of the after period crashes on the treatment group. M and N represent the five-year averages of the before and after period crashes, respectively, on the comparison group. The final value in TABLES 11 through 14 is percent change in crashes, which shows the effectiveness of the treatment on safety.

TABLE 11 Results for Intersection 1 (Treatment: Signalization)

Crash Type	$\hat{\kappa}$	var(κ)	Θ	var(Θ)	K	L	M	N	Percent Reduction in Crashes	FHWA Urban 3-Leg CRP
Injury	0.55	1.09	1.55	0.19	1.80	5.00	0.18	0.20	-55*	+14
PDO	1.82	2.69	0.68	0.07	5.40	6.60	0.36	0.49	+32	Not available
Total	2.73	6.74	0.87	0.14	7.20	11.60	0.55	0.69	+13	Not available
Rear End	0.55	0.79	1.37	0.08	2.80	5.20	0.11	0.09	-37*	-50*
Sideswipe	0.91	1.29	0.69	0.01	0.20	0.40	0.15	0.02	+31	Not available
Angle	0.36	0.00	0.65	0.02	2.00	1.20	0.07	0.25	+35	+34
Turning	0.18	0.15	0.00	0.00	1.40	3.80	0.04	0.00	+100	Not available

*Negative value indicates an increase in crashes

TABLE 12 Results for Intersection 2 (Treatment: Signalization)

Crash Type	$\hat{\kappa}$	var(κ)	Θ	var(Θ)	K	L	M	N	Percent Reduction in Crashes	FHWA Urban 4-Leg CRP
Injury	1.79	1.95	0.29	0.01	1.60	1.00	0.36	0.38	+71	+23
PDO	3.43	0.00	0.21	0.01	2.80	1.40	0.63	0.73	+79	Not available
Total	5.07	25.28	0.28	0.02	4.40	2.40	1.01	1.15	+72	Not available
Rear End	0.50	3.88	0.45	0.01	0.20	0.40	0.10	0.19	+59	-38
Sideswipe	0.64	0.37	0.00	0.01	0.20	0.00	0.13	0.12	+100	Not available
Angle	1.79	3.88	0.25	0.01	3.20	1.60	0.36	0.47	+75	+67
Turning	0.50	0.11	0.24	0.00	0.40	0.20	0.10	0.07	+76	Not available

TABLE 13 Results for Intersection 3 (Treatment: Signalization)

Crash Type	$\hat{\kappa}$	var(κ)	Θ	var(Θ)	K	L	M	N	Percent Reduction in Crashes	FHWA Urban 4-Leg CRP
Injury	1.93	0.96	0.54	0.05	2.75	3.17	0.46	0.52	+46	+23
PDO	2.26	4.01	0.28	0.02	2.25	2.17	0.54	0.87	+72	Not available
Total	4.22	8.69	0.39	0.04	5.00	5.33	1.02	1.44	+61	Not available
Rear End	0.81	0.30	0.21	0.00	1.00	0.50	0.20	0.20	+79	-38
Sideswipe	0.39	0.00	0.14	0.00	0.00	0.17	0.08	0.10	+86	Not available
Angle	1.56	2.69	0.35	0.02	3.25	3.83	0.38	0.76	+65	+67
Turning	0.37	0.16	0.92	0.03	0.00	0.67	0.09	0.08	+8	Not available

TABLE 14 Results for Intersection 4 (Treatment: Conversion to SLA)

Crash Type	$\hat{\kappa}$	var(κ)	Θ	var(Θ)	K	L	M	N	Percent Reduction in Crashes	FHWA Rural 4-Leg CRP
Injury	2.32	5.18	0.08	0.00	1.80	0.25	0.48	0.52	+92	Not available
PDO	4.21	0.00	0.04	0.00	0.80	0.25	0.78	0.83	+96	Not available
Total	6.32	0.00	0.09	0.00	3.00	0.75	1.19	1.37	+91	Not available
Rear End	1.18	0.00	0.00	0.00	0.20	0.00	0.22	0.10	+100	Not available
Sideswipe	0.61	0.00	0.33	0.01	0.00	0.25	0.13	0.08	+67	Not available
Angle	2.96	0.00	0.10	0.00	2.60	0.50	0.55	0.75	+90	Not available
Turning	0.64	0.00	0.00	0.00	0.00	0.00	0.12	0.12	+100	Not available

TABLES 11 through 14 show a 100 percent reduction for certain types of crashes (e.g., rear-end and turning crashes in TABLE 14). These values have been determined due to the nature of the method used for the analysis; a zero value for the quantity “L” will return results implying 100 percent reduction in crashes, regardless of the characteristics of the comparison group. This is a limitation of the method that is sometimes encountered when crashes of a certain type are not experienced in the after period of a treatment.

Another aspect of the results is the negative values in the “percent reduction in crashes” column. This implies that the method shows an increase in crashes after application of the treatment. TABLE 11 shows two examples of this for injury crashes and rear-end crashes. The method shows that at Intersection 1, more injury and rear-end crashes occurred after signalization. One of the consequences of signalization is often an increase in rear-end crashes. This is not unusual, as evidenced by a comparison with crash reduction percentages from the FHWA (28). What *is* unusual is seeing a decrease in rear-end crashes for Intersections 1 and 2. This may indicate that MLAs experience a higher than normal probability of rear-end collisions than signalized intersections. The cause may be linked to the ISD blockage by adjacent vehicles and jockeying of positioning by drivers to better see approaching through vehicles on the major roadway. Injury accidents decreased more than expected in comparison to the FHWA values at all 3 locations that were signalized and angle crash reduction percentages were very similar to the FHWA estimated percentages which confirms the correct choice of methodology.

Crash Rate Comparison Study

TABLE 15 shows the univariate 3-factor ANOVA table for Hypotheses 3 and 4 based on a total of 90 intersections. In addition to the main effects and their interactions, terms for the Corrected Model and Intercept are also shown. The Corrected Model accounts for variation in the dependent variable (average crash rate) which is due to factors other than the intercepts that are included in the model. The intercept represents the overall mean.

TABLE 15 3-factor ANOVA for Crash Rates

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Corrected Model	10.7	15	0.714	2.07	**0.020**
Intercept	14.2	1	14.2	41.2	**0.000**
INT_TYPE	2.35	2	1.18	3.42	**0.038**
TWOLANES	0.004	1	0.004	0.012	0.912
SPD_LMT	0.696	2	0.348	1.01	0.369
INT_TYPE * TWOLANES	0.518	2	0.259	0.752	0.475
INT_TYPE * SPD_LMT	2.44	4	0.611	1.77	0.143
TWOLANES * SPD_LMT	0.145	2	0.07	0.210	0.811
INT_TYPE * TWOLANES * SPD_LMT	0.01	2	0.05	0.143	0.867
Error	27.2	79	0.345		
Total	59.0	95			
Corrected Total	37.9	94			

INT_TYPE: MLA stop-controlled, SLA stop-controlled or signalized
TWOLANES: Two through lanes on major road, 4 through lanes on major road
SPD_LIMIT: 45 mph or less, 50 mph or 55 mph, 60 mph or more
BOLD print indicates statistical significance at the 95 percent confidence level

As shown in the table, several factors are significant at a 95 percent level of confidence. The significance is judged from the F-Statistic (for which the critical value is 2.46 at the 95 percent confidence level). A value of F in the ANOVA table greater than 2.46 indicates statistical significance at the 95 percent confidence level. Another method of judging significance is in "Significance" column. A value in this column less than 0.05 indicates significance at the 95 percent confidence level. No interactions are significant which enables the use of post-hoc tests on the means, particularly those of intersection type "INT_TYPE", which ANOVA indicates is significant. Post-hoc tests are statistical techniques designed to find which sets of means are different, and some provide the magnitude of the difference between the means.

As shown in TABLE 16, removal of the interactions still results in significant factors. However, the variable of interest (INT_TYPE) is not significant, so no further action is taken.

TABLE 16 3-Factor ANOVA with Interactions Removed

Source	Type III Sum of Squares	Df	Mean Square	F	Significance
Corrected Model	6.74	5	1.35	3.84	**0.003**
Intercept	26.6	1	26.6	75.9	**0.000**
INT_TYPE	1.50	2	0.748	2.13	0.125
SPD_LMT	4.05	2	2.02	5.77	0.004
TWOLANES	0.05	1	0.06	0.161	0.689
Error	31.2	89	0.351		
Total	59.1	95			
Corrected Total	37.9	94			

BOLD print indicates statistical significance at the 95 percent confidence level

Since there are significant mean differences shown in TABLE 16 between like categories of intersections in the MLA pool and the sample population, inferences can be made as to whether MLA stop-controlled intersections exhibit better or worse crash rates than single-lane approach intersections in the state of Nebraska.

Using post-hoc tests, calculated using SPSS software, the differences between the means may be estimated. Two post-hoc tests are used. Tukey's HSD Test assumes equal variance among the mean crash rates, while Dunnett's C Test does not. Both tests yielded the same results, which showed that MLA stop-controlled intersections have an average mean crash rate that is less than that of SLA intersections by 0.49 crashes per million entering vehicles per year. These results are detailed in TABLE 17. A value for significance less than 0.05 indicates that the mean difference is statistically significant. Tukey's HSD calculates a value for significance, while Dunnett's C does not.

TABLE 17 Summary of Post-Hoc Tests

Test	Intersection Type	Intersection Type	Mean Difference	Significance
Tukey's HSD	MLA Stop-Controlled	SLA Stop-Controlled	-0.49	**0.03**
		Signalized	-0.05	0.99
Dunnett's C	MLA Stop-Controlled	SLA Stop-Controlled	-0.49	N/A
		Signalized	-0.05	N/A

BOLD print indicates statistical significance at the 95 percent confidence level

The results in TABLE 17 show that Hypothesis 3 is not confirmed. Hypothesis 4, however, is confirmed since there is no statistically significant difference between the mean crash rates of MLA stop-controlled intersections and signalized intersections. Additional analyses conducted to include all factors noted in Chapter 1 are shown in Appendix E. One of these additional analyses showed significant results, so they are both included for completeness.

Chapter 6
CONCLUSIONS AND RECOMMENDATIONS FOR SAFETY ASPECT

Before-After Comparison Group Studies

The main conclusion to draw from the first set of analysis is that signalization or conversion to SLA of MLA stop-controlled intersections improved safety at intersections that were MLA previously. Results particular to the signalization study found that at the three-legged intersection, US Highway 6 and 56th St in Lincoln, safety conditions became worse in the after period for injury and rear-end crashes. It is intuitive to expect more rear-end crashes when intersections are signalized, but this is the only intersection amongst the four to show an increase in injury and rear-end crashes. Both four-legged intersections that were changed from MLA stop-control to signal control benefited from the treatment, with reductions in crashes across the board. Of particular interest are the large reductions in numbers of injury and total crashes. Confirming Hypotheses 1 and 2 outlined in Chapter 1, angle crashes changed in frequency in all three cases by the treatment action, in this case with a positive effect on safety. The principle inference drawn from this portion of the study is that signalization of stop-controlled MLA stop-controlled intersections improves safety.

The second before-after comparison group study, which examined lane removal as a treatment to improve safety at MLA stop-controlled intersections found that safety improved in all investigated areas. Total crashes reduced by 91 percent, and injury crashes were reduced by 92 percent. Some results indicated that the treatment resulted in 100 percent reduction in a certain type of crash on these intersections. These and the other relatively high numbers are due to the small number of crashes during both the before and after periods. However, an inference from the results is that conversion of MLA stop-controlled intersections to SLA stop-controlled intersections results in safety improvement.

Further research could be conducted in order to allow these studies to give more insightful results. A larger comparison group for Intersection 1 would help, although a better solution might be to find another three-legged intersection that underwent a similar modification to find if the results of this analysis would be similar.

Another area of expansion to this method is to account for confounding variables that may influence the results of the study. Traffic volume changes were accounted for in this study, but other factors may have influenced conditions such as differences in weather during the before-after periods and uneven land use development surrounding certain intersections in either the study group or the comparison group.

Crash Rate Comparison Study

The average crash rate comparison study which tested Hypotheses 3 and 4, produced results that conflicted with the crash frequency comparison study. Appendix D shows the complete data set used for testing, and it shows that the comparison pool obtained for this study had several intersections with comparatively large mean crash rates. In this case, it is felt that larger pools of data are necessary to gain truly random sampling. If larger sample populations were available, different findings may result.

Based on the results of the analysis using the available data, MLA stop-controlled intersections are safer than SLA stop-controlled intersections, however there is no statistically significant difference between average crash rates at MLA stop-controlled intersections and signalized intersections.

Recommendations

Further study with more complete data pools than were available at the time this project was executed should be included before making design decisions based on the results of the analysis studying crash rate. Conversion of MLA stop-controlled intersections to single lane approaches should be considered in Nebraska. This option may cost less than signalization, but traffic capacity and delays must be taken into account before that decision can be made. A safety evaluation at each proposed or existing MLA stop-controlled intersection should be undertaken, and where warranted, signalization of intersections with multiple lanes approaching a stop sign should be considered in the interest of public safety.

Chapter 7
TRAFFIC VOLUME CHARACTERISTICS OF MLA-TYPE INTERSECTIONS

Background

As mentioned in Chapter 4, the study sites for this research are comprised of 3- and 4-leg intersections with a wide variety of lane configurations. Each intersection has the shared characteristics of being two-way stop-controlled and of having approaches to the stop signs that exhibit more than one lane. All 40 of the intersections used for the sample population of MLA stop-controlled intersections are in the state of Nebraska, and are scattered across the state. A majority of the sites are rural intersections of state and federal highways. A complete listing with basic information such as location, ADT, posted speed limit, geometry, and 3-yr accident rate of each of the MLA intersection sites may be found in Appendix B.

Search for Optimal Major-Minor Volume Ratio for Use of MLA-Type Intersections

Intersection accident rates are associated with the number of conflicting traffic volumes. A study was completed to determine if there was a relationship between the major and minor road average daily traffic values (ADTs) that would suggest a maximum optimal major-minor volume ratio (or conflict interaction level) which would indicate when an MLA intersection design alternate should be considered for implementation. Those MLA-type intersections with 3-year accident rates less than the statewide average 3-year accident rates were used as a database for the study. NDOR began compiling statistics for 3-year average accident rates in June of 2003. The earliest period available that was near the time of compilation of the study database which could be used for comparisons was only a 2-year average so the latest available 3-year period was used for comparison purposes. The 3-years averages for the database sites, the 2-year statewide averages and latest 3-year statewide averages are show in TABLES 19 and 20.

The four intersections investigated in the before-and-after comparison group studies listed in TABLE 11 were not included in the database, since those intersections warranted some change in configuration to improve safety during the study period. The database was further reduced to 26 sites with a major road posted speed of 55 mph or higher since MLAs at high-speed intersections were the main concern of the NDOR technical advisory committee group. The sites were divided into two categories, thought to possibly have an influence on the results:

1) 2-lane major road, and
2) 4-lane major road.

TABLE 18 shows detailed characteristics of the 18 2-lane-major-road sites studied.

TABLE 18 Characteristics of High Speed MLA Intersections, 2-Lane Major Roads

Site No.	Site Location	Site Area Type	Major Rd Posted Speed	Intersection Complexity	Major Road Alignment	Site 3-Year Accident Rate	2-Year State Average 6-1-03 to 6-30-05	3-Year State Average 1-1-06 to 12-31-08
11	US26 & N61	Rural	65	Simple	Tangent	0.000	0.406	0.301
12	US30 & N19	Rural	60	Simple	Tangent	0.000	0.406	0.301
13	US30 & L-56G	Rural	60	Simple	Horiz Crv	1.883	0.406	0.301
14	US34 & N1	Rural	60	Simple	Tangent	0.213	0.406	0.301
16	US75 & US 73	Rural	60	Simple	Tangent	0.000	0.406	0.301
17	US75 & N4	Rural	60	Simple	Tangent	0.000	0.406	0.301
23	US81 & N121	Rural	60	Simple	Tangent	0.159	0.406	0.301
25	US81 & N12	Rural	60	Simple	Horiz Crv	0.867	0.406	0.301
29	US183 & N4	Rural	65	Simple	Tangent	0.894	0.406	0.301
35	US26 & L-62A	Rural	65	Complex	Tangent	0.250	0.524	0.711
40*	N13 & N121	Rural	60	Simple	Tangent	0.348	0.406	0.301
42	N50 & N4	Rural	60	Simple	Horiz Crv	0.599	0.406	0.301
43	US34 & N61	Rural	60	Simple	Tangent	0.000	0.406	0.301
44	S N61 & N92	Rural	60	Simple	Tangent	0.000	0.406	0.301
46	N92 & N39	Rural	60	Simple	Tangent	0.483	0.406	0.301
48	W N92 & US 26	Rural	60	Simple	Tangent	0.297	0.406	0.301
49	S N92 & US 385	Rural	65	Complex	Tangent	0.403	0.524	0.711
51	S N99 & N8	Rural	60	Simple	Tangent	0.000	0.406	0.301

Simple indicates all legs intersect at one point. **Complex** indicates an intersection with a ramp, cutoff, or any design that doesn't intersect at one point.
Shading indicates study site 3-Yr accident rate greater than statewide average
*Site 20 had a less than average rate than the 2003-5 statewide average but a greater than average rate for the 2006-8 statewide average. It was not used in the development of the following equations.

Table 19 shows details of the eight 4-lane major road sites.

TABLE 19 Characteristics of High Speed MLA Intersections, 4-Lane Major Roads

Site No.	Site Location	Site Area Type	Posted Speed	Intersection Complexity	Major Road Alignment	Site 3-Yr Acc Rate	2-Yr State Avg 6-1-03 to 6-30-05	3-Yr State Avg 1-1-06 to 12-31-08
3	W US6 & US 281	Urban	60	Simple	Tangent	0.917	0.630	0.690
5	US6 & US 283	Urban	65	Simple	Tangent	1.032	0.630	0.690
6	US6 & S-1C	Urban	60	Simple	Tangent	0.313	0.630	0.690
8	US20 & N110	Rural	60	Simple	Tangent	0.349	0.479	0.379
20	US81 & L-85F	Rural	60	Simple	Tangent	0.242	0.479	0.379
21	US81 & S-85H	Rural	55	Simple	Tangent	0.000	0.479	0.379
45	E N92 & N15	Rural	60	Simple	Tangent	0.388	0.406	0.301
47	W N92 & N79	Rural	60	Simple	Tangent	0.802	0.406	0.301

Simple indicates all legs intersect at one point.
Shading indicates study site 3-Yr accident rate greater than statewide average

Sites in the 2-lane major road category were first separated by posted speeds of 60 and 65 to determine if posted speed had an impact on the major-minor volume ratio relationship. FIGURES 11 and 12 show the developed best-fit equations and their resulting adjusted R^2. There were only 3 sites in the 65 mph posted speed category so the 0.91 adjusted R^2 value of the counterintuitive results of the best-fit curve are not further considered. All posted speed categories were then combined to develop the best-fit curve shown in Figure 13. The adjusted R^2 value of 0.26 suggests a poor relationship between major and minor road traffic volumes as a predictor of suitable sites for MLA-type intersections. One characteristic of MLA-type intersections with higher than average 3-year accident rates was horizontal curvature on the major road at or very near the point of intersection. Three of the 6 sites removed from the database due to higher than average rates were of this major-road-alignment character which may indicate that MLA-type intersections are not well suited to this type of situation.

Sites with 4-lane major roads had so few occurrences in the database (four), they were compiled into all posted speed groups and a best-fit equation was developed. FIGURE 14 shows the results. Although the adjusted R^2 value is 0.60, since so few sites were available it is doubtful that the equation is a good predictor of suitable MLA-type intersections along 4-lane major road facilities. However, two of the four 4-lane major road sites that were removed from the database due to the 3-year accident rate being higher than the statewide average were in urban areas which may indicate that urban scenarios are not well suited for MLA-type intersections connecting to 4-lane major facilities.

FIGURE 11 Results of Major ADT vs Minor ADT Relationship at Intersections of 2-Lane, 2-Way Roadways with Below Average 3-yr Accident Rates, Major Rd Speed Limit = 60 mph

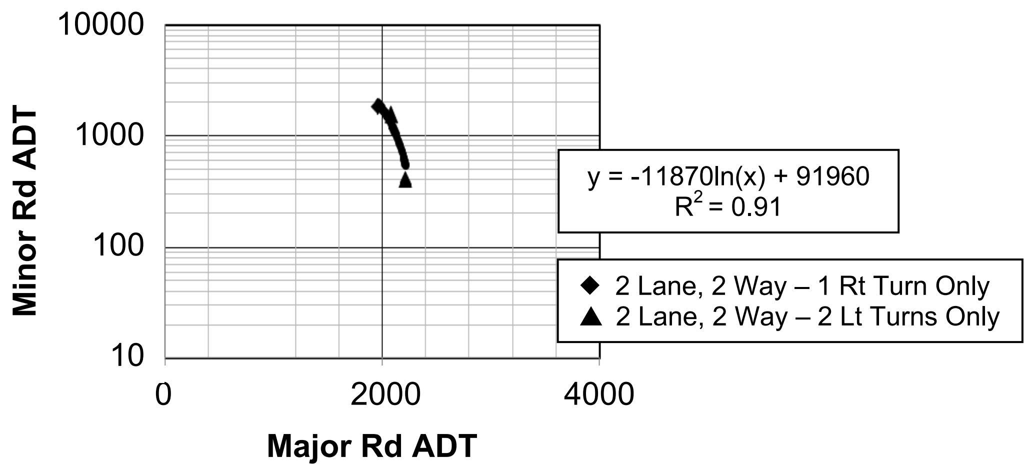


FIGURE 12 Results of Major ADT vs Minor ADT Relationship at Intersections of 2-Lane, 2-Way Roadways with Below Average 3-Yr Accident Rates, Major Rd Speed Limit = 65 mph

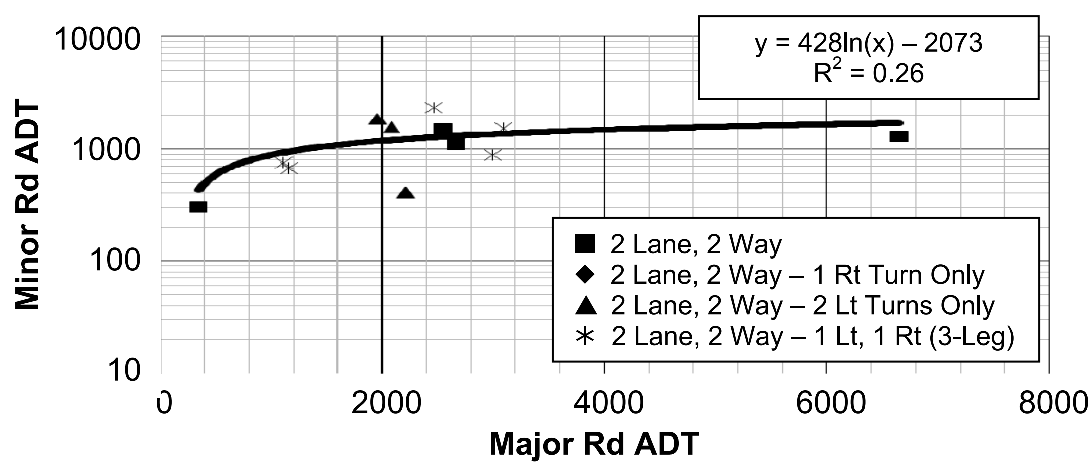


FIGURE 13 Results of Major ADT vs Minor ADT Relationship at Intersections of 2-Lane, 2-Way Roadways with Below Average 3-Yr Accident Rates, Major Rd Speed Limits = 60 and 65 mph

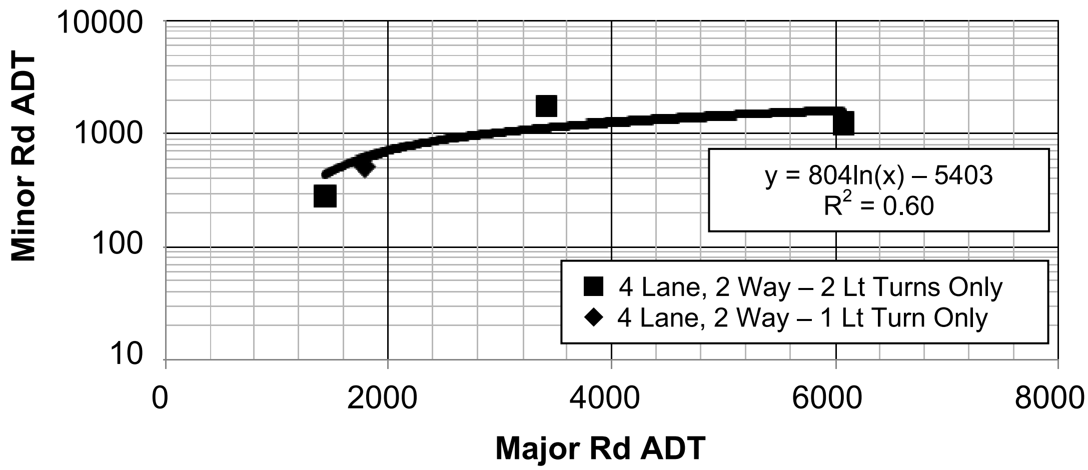


FIGURE 14 Results of Major ADT vs Minor ADT Relationship at Intersections of 4-Lane, 2-Way Roadways with Below Average 3-Yr Accident Rates, Major Road Speed Limit = 60 and 65 mph

Chapter 8
BACKGROUND OF TRAFFIC OPERATIONS AND DRIVER BEHAVIOR AT MLA-TYPE INTERSECTIONS

Driver Behavior Aspect

As outlined in Chapter 1, many MLA intersections will remain in use or be built in the future to reduce driver delay regardless of the outcome of the safety studies discussed in the previous chapters. These locations will not meet warrants for signalization and/or will be in remote areas of Nebraska where installation of a signal for operational purposes will have negative safety impacts for other reasons. Wide-throated single-lane approach (SLA) intersections that have been constructed to accommodate the turning footprint of large trucks can also function as MLA intersections when two vehicles on the stopped approach are small relative to the paved surfacing available. This results in drivers lining up adjacent to each other as shown in FIGURE 3, repeated below for convenience. If the paved area to the right of a stopped left/through vehicle is wide enough to safely pass, a right-turning driver will generally do so, pull forward of the left/through vehicle to view non-stopping traffic on the major road, and choose an acceptable gap to make a right turn and enter the major road traffic stream.

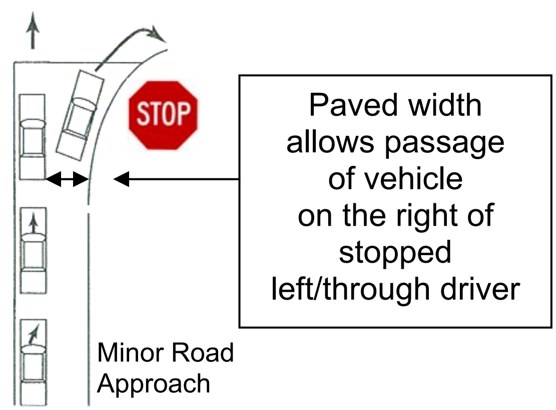


FIGURE 3 Illustration of a Flared Intersection Approach that Functions as an MLA-Type Intersection (12, Highway Capacity Manual, Exhibit 17-18, pg. 17-21)

Therefore, in addition to the study of the safety of MLAs relative to SLAs and signalized intersection types, it is necessary to study driver behavior at such locations to determine what behavior the current driving environment induces from drivers based on their experience and view of the appropriate driving practice in a given situation.

According to the Green Book (29, AASHTO, 2004), one of the most important ways to aid positive driver performance is to develop a three-dimensional driving environment in accordance with prevalent driver expectancies. The following principles are encouraged for any physical roadway system:

- Design elements should be applied consistently throughout a system segment,
- Consistency should be maintained from one segment to another throughout a transportation agency's jurisdiction, as well as nationally, and
- Unusual design features should be avoided since these can confuse drivers.

When drivers receive information they expect from their surroundings with respect to roadway geometric and traffic control devices, their performance tends to be nearly error free. When an unfamiliar and unexpected situation arises, errors in judgment of how to respond appropriately may result.

Driver expectancies are formed by experience and training of the drivers themselves. Situations that are readily recognized, accurately perceived, and successfully responded to are incorporated into each individual's frame of reference for similar situations in the future. Driving environments that are familiar and that redundantly stimulate positive driving behavior affect how drivers perceive and respond to stimuli.

Background on Driver Expectancy

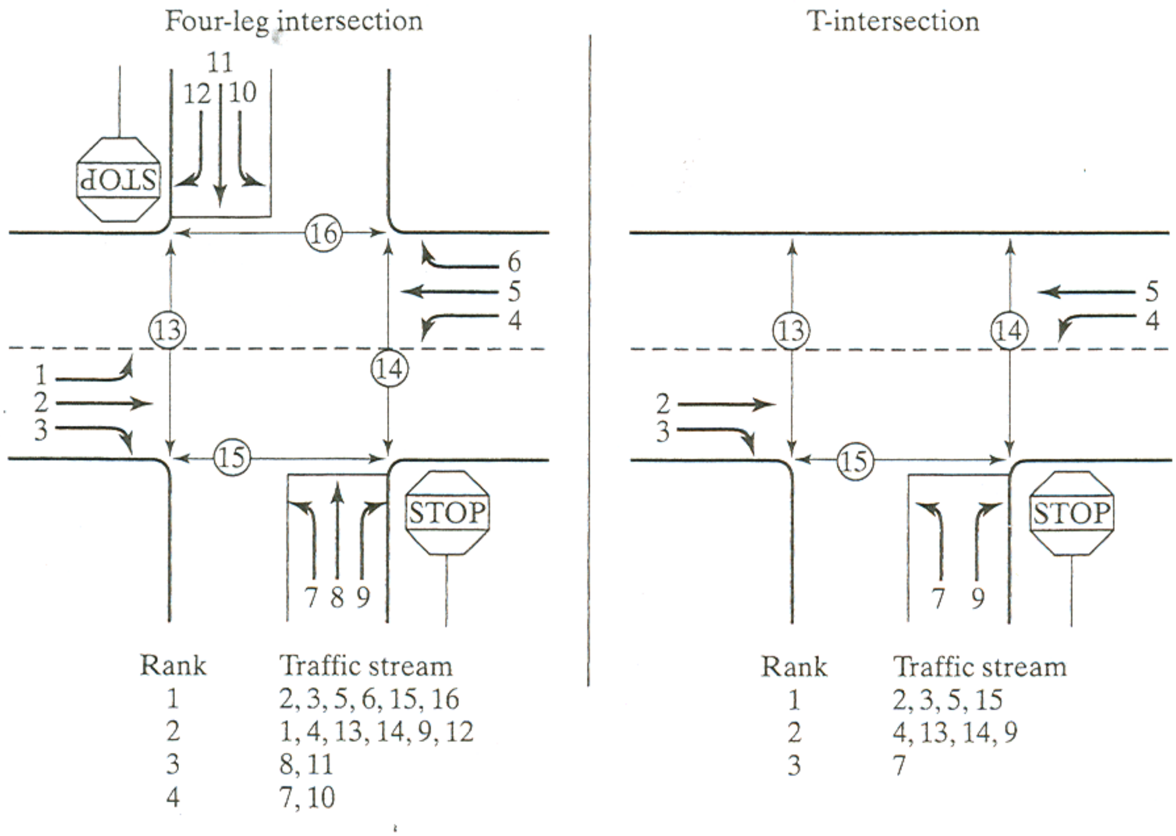
There are two ways in which drivers gain experience and retain it for future use.

1. ***A priori*** driver expectancy results from the body of knowledge, skills and ability a driver brings to the driving task from previous training or the successful completion of safe control of the vehicle in similar situations. This has a direct affect on how a driver perceives and reacts to a given situation.
   Example: A driver familiar with driving multi-lane freeways in the United States expects to exit the freeway from the right-most lane of any number of through driving lanes in his/her direction of traffic. An appropriate driver behavior would be to gradually maneuver the vehicle to the right-most lane in advance of the exit location, choosing acceptable gaps in traffic to do so.
2. ***Ad hoc*** driver expectancy is driver behavior that is modified in real time due to knowledge gained immediately from a given situation.
   Example: A driver approaches a series of speed bumps within his/her traffic lane and approaches the first one at what is believed to be a reasonable speed for the perceived 3-dimensional characteristics of the traffic control device. If the driver crosses the first speed bump too fast, the result will be a negative driver comfort experience (abrupt jolt in vehicle's suspension system), resulting in a modification of speed (braking) before crossing the next speed bump.

Any geometric recommendations that result from this part of the study must conform to these types of driver expectations in order to be successful.

FIGURE 4 is reproduced below to show the priority of movements at a two-way stop-controlled intersection which would be included in the ***a priori*** driver frame of reference. As described previously, according to these guidelines, if a left- and right-turning vehicle are simultaneously stopped at the same stop-controlled approach, the right-turning vehicle has priority over the left. The right-turning driver only requires a suitable gap in traffic from the major road approaching the intersection from his/her left side instead of conflicts from the left, far and right sides. A left-turning vehicle has the lowest priority of all movements due to the number of potential conflicts that must be considered by the driver.

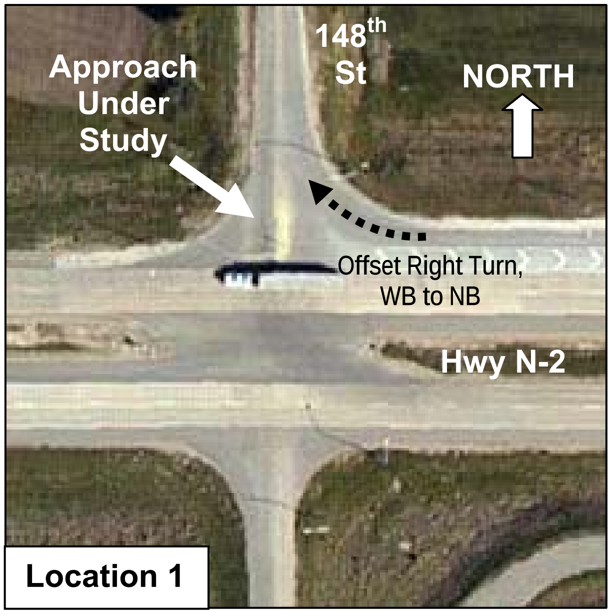
FIGURE 4 Priority of Vehicle and Pedestrian Movements at a 2-Way Stop-Controlled Intersection (12, Highway Capacity Manual, Exhibit 17-3, pg. 17-4)



This fact is exhibited in physical evidence collected at MLA approaches. Right-turning drivers have the expectation at a stop-controlled intersection with sufficient paved surface that they may pull forward of a left/through stopped vehicle on the same approach, look for an appropriate gap in through traffic approaching from their left and enter the flow of traffic safely. Therefore, any three-dimensional features or traffic control device cues that reinforce that conviction should be used to encourage right-turn drivers to perform that behavior in this situation. If the position of the right-turning driver can be accurately estimated, an optimal position for the left/through driver can be encouraged as well, resulting in the optimal condition for vehicles within a less-than-desirable intersection sight distance situation. FIGURE 15 shows an example of such a situation at a stopped-control intersection south of Lincoln, NE at the easternmost junction of US Hwy 77 (expressway) and Nebraska Hwy 41 (two-lane two-way highway). The photograph was taken from a pole-mounted camera as part of a current NDOR research study on offset right-turn lanes (ORTLs) titled *"Conditions Warranting Offset Right-Turn Lanes (ORTL) for Improved Intersection Sight Distance"*, (NDOR Project SPR-P1(06)P592).

FIGURE 15 Photograph of Typical Driver Behavior at MLA Intersection, US Hwy 77 & East Junction N-41

As part of the ORTL research project, the effectiveness of adding a “Stop at Line” sign on a 2-way stop-controlled approach was studied. Two stopped approach locations were chosen for data collection, both of which had raised center medians with a STOP sign within the raised median and a STOP sign on the right side of the approach as well. Vehicle stopping positions were recorded at both locations under varying conditions. Location 1 was at the intersection of 148th Street and Hwy N-2 to the southeast of Lincoln, NE. Location 2 was at the easternmost intersection of Hwy US-77 and Hwy N-41 between Lincoln and Beatrice. Both N-2 and US-77 are 4-lane divided expressways and both 148th St and N-41 are 2-lane roadways. Location 1 has an offset right-turn lane to the left of the 148th St stop-controlled approach (for the WB to NB right-turn movement) and Location 2 has a traditional right-turn lane to the left of the N-41 stop-controlled approach (NB to EB right-turn movement). Aerial views of both locations are shown in FIGURE 16.



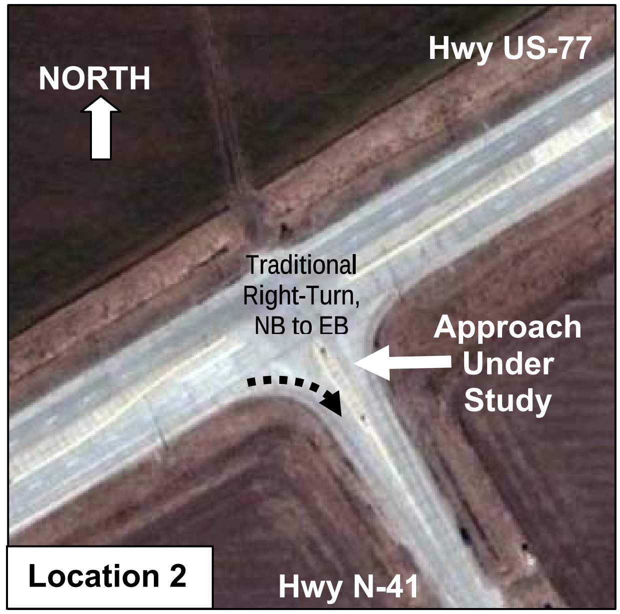


FIGURE 16 Study Locations 1 and 2 from Offset Right-Turn Lane (ORTL) Project

Data was collected at Locations 1 and 2 under three scenarios:

- **Scenario 1 - BEFORE** was before anything was changed at the intersection. Stop bars at both locations were "freshened" before any information was collected to make sure that they were in the best condition possible to be viewed by drivers. Data was collected for a period of five consecutive 12-hour days to ensure that enough stopped vehicles were recorded for a statistically significant interpretation of the results.
- **Scenario 2 - AFTER** involved collecting video for five consecutive 12-hour days one week after the installation of the "STOP AT LINE" sign. The week delay was to make sure drivers were acclimated to the modified sign.
- **Scenario 3 – EXTENDED STUDY (or ES)** included five consecutive 12-hour videos of driver stopping behaviors 4 weeks after the "STOP AT LINE" sign was installed to determine if the sign had a diminishing effect over time.

The video from the ORTL study was reduced to collect driver behavior information to substantiate the expectation that right-turning drivers at MLA-type intersections. This was done to understand their position in the hierarchy of intersection movement priorities (shown in FIGURE 4) and take advantage of this knowledge by moving ahead of view-blocking left-turn vehicles, turning right when a suitable gap in major road traffic from the left is available.

All occurrences of left-right vehicle conflicts on the ORTL video were viewed to determine the likelihood of the behavior described above. Results are shown in FIGURE 17 which indicates that right-turning drivers pull forward of view-blocking left-turning vehicles and leave before the left-turning drivers the majority of the time.

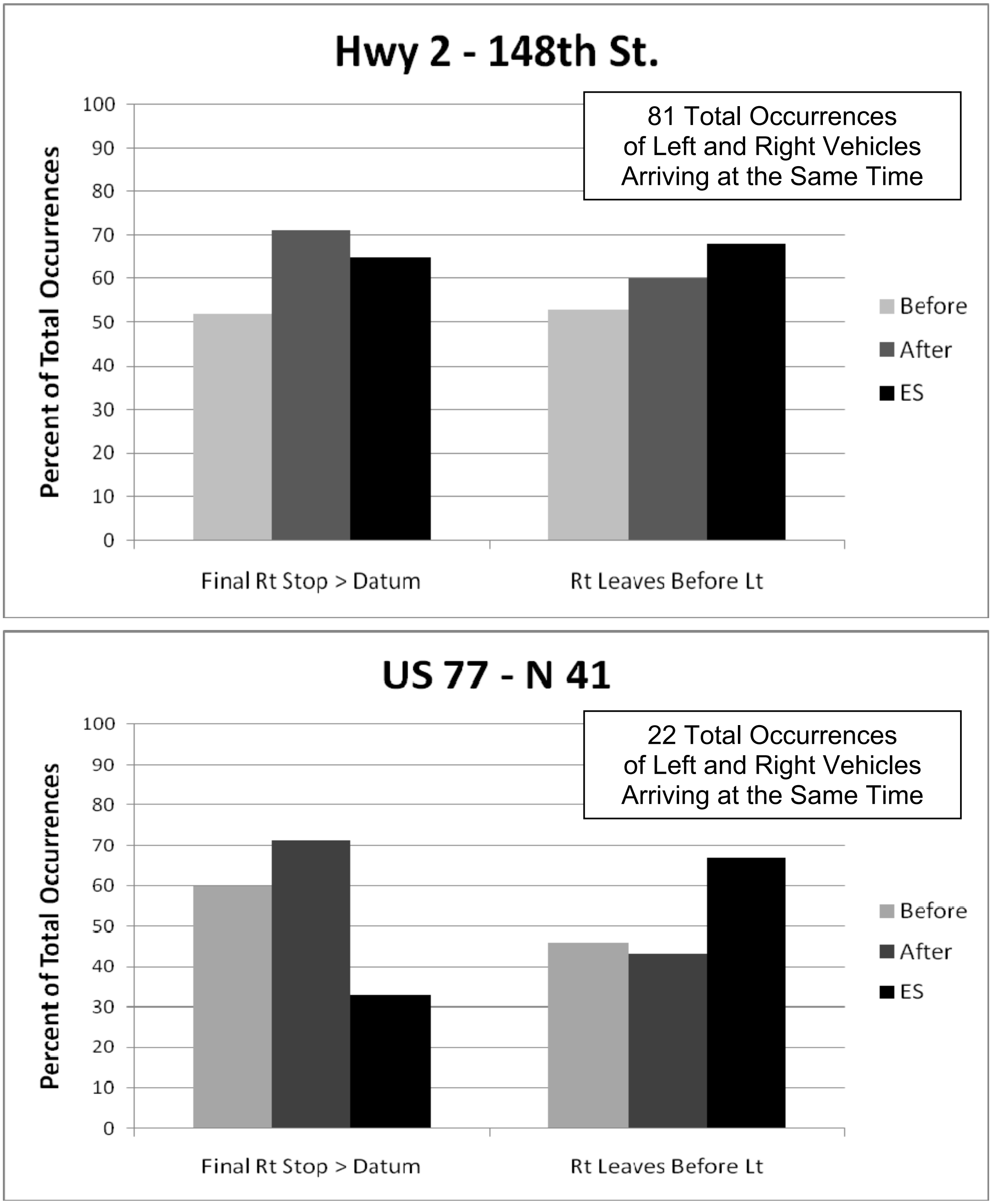


FIGURE 17 Results of Right-Turning Driver Behavior at MLA Type Intersections at Location 1, 148th St and Hwy 2 and Location 2, US Hwy 77 and Hwy N-41

Chapter 9
MISCELLANEOUS FIELD STUDIES TO DETERMINE OPTIMAL VEHICLE POSITIONING AT MLA-TYPE INTERSECTIONS

Driver Compliance with Staggered Stop Bars

A field study was performed to observe how drivers comply with staggered stop bar paint lines at intersections. There are several locations at signalized intersections within the city of Lincoln, NE that exhibit staggered stop lines. The purpose of the striping configuration is primarily to allow large left-turning vehicles enough clearance to maneuver without conflicting with cross-street left-turning vehicles stopped at the signal. A typical configuration for a staggered stop bar is shown in FIGURE 18 along the east-west roadway approaches.

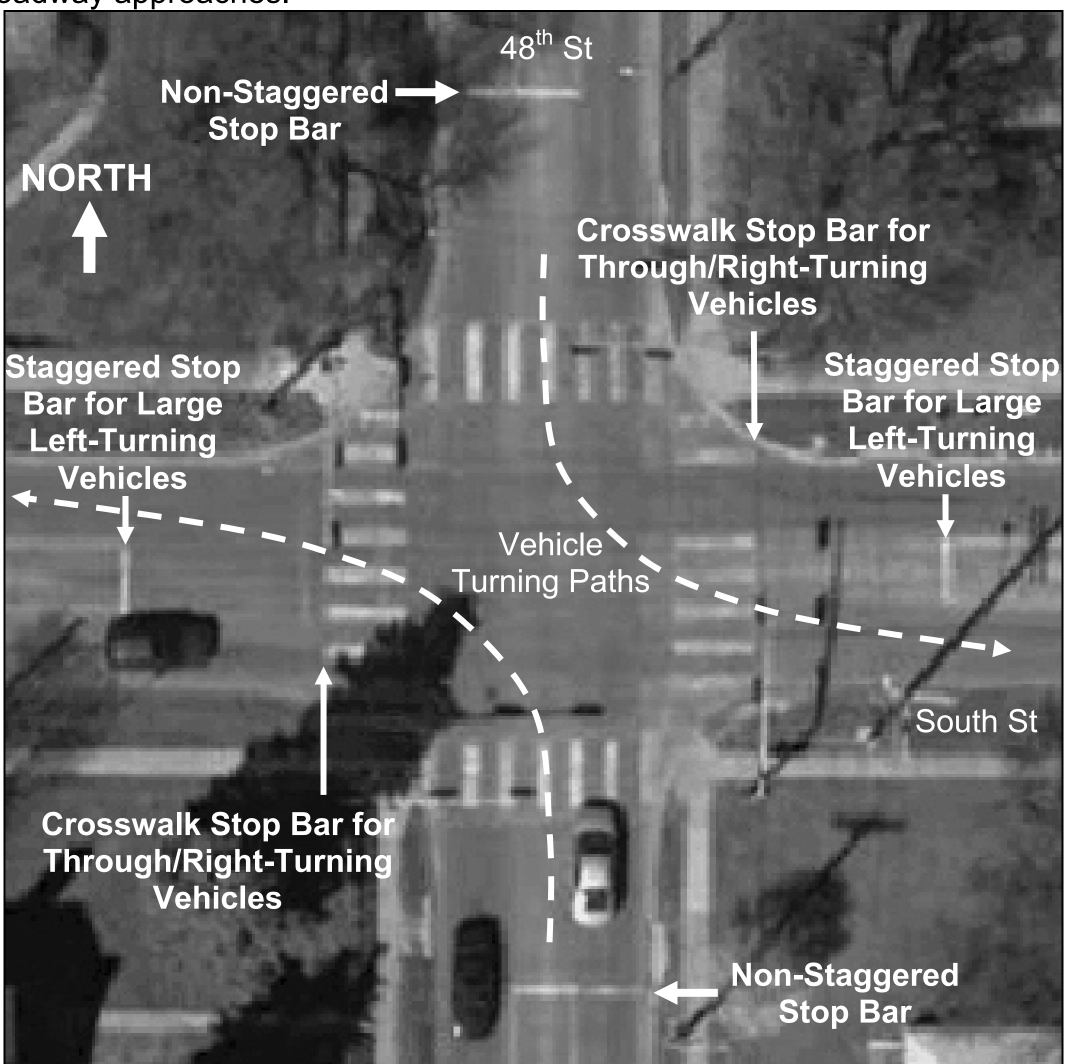


FIGURE 18 Aerial View of Staggered Stop Bar at 48th & South Sts in Lincoln, NE.

Although this research project was concerned with 2-way stop-controlled intersections, it was necessary to observe driver compliance with a staggered stop bar situation since it is proposed as a part of an optimal solution to the multiple-lane approach issue. The difference in traffic control devices (i.e. traffic signal versus stop-sign control) may be pertinent to driver behavior but no staggered stop bar sites at stop signs were found in the Lincoln-Omaha area to study in order to make a judgment on whether drivers comply with the pavement marking intent.

Field Study Methodology

The intersection of 10th and Charleston Streets in Lincoln, NE shown in FIGURE 19 was selected as an appropriate study site for an accurate assessment of driver behavior at a signalized intersection with a staggered stop bar. At this intersection, the left-turn lane stop line for the eastbound to northbound movement is set back 10 feet from the straight/right-turn stop line which also serves as the near boundary for the crosswalk striping. Another view of the study intersection approach is shown in FIGURE 20. After review of the MUTCD guidelines (7, MUTCD, 2003) and discussions with Traffic Division authorities at NDOR, the desirable position for stopping at the stop bar was considered to be with the front edge of the front bumper of a stopped vehicle at the near edge of the stop bar, as shown in FIGURE 21.

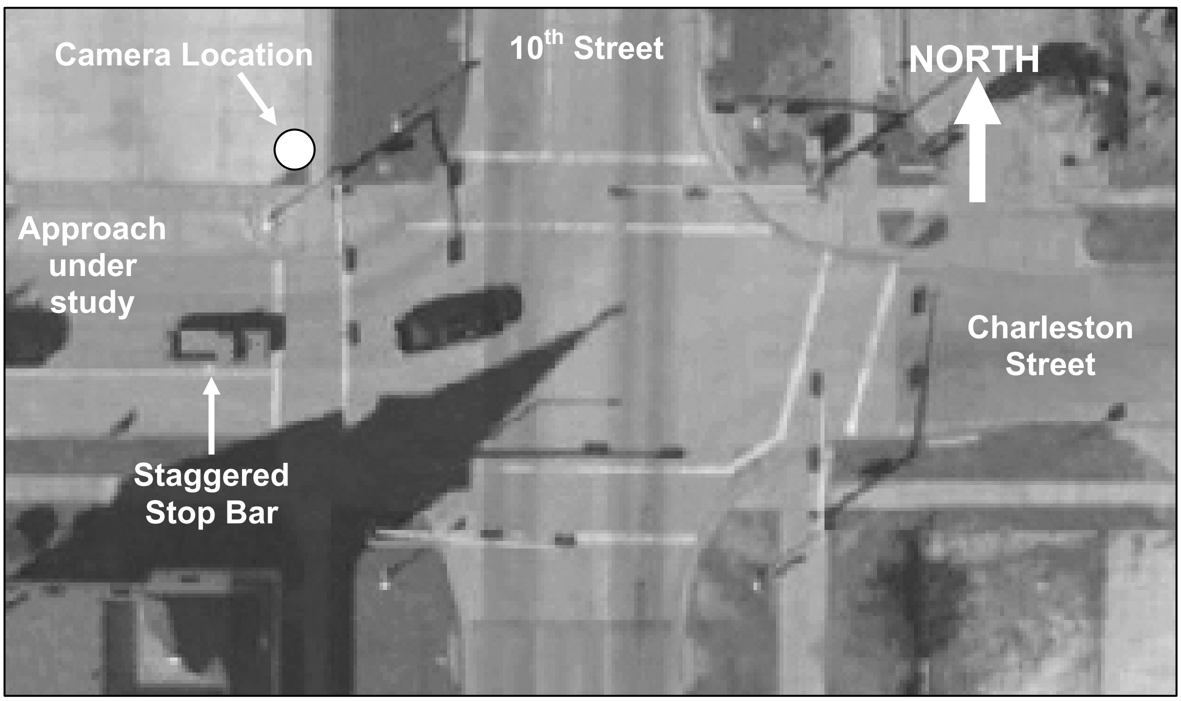


FIGURE 19 Aerial View of Staggered Stop Bar Study Site at 10th and Charleston Sts in Lincoln, NE.

FIGURE 20 View of Staggered Stop Bar on Eastbound Approach to 10th and Charleston Sts, Lincoln, NE.

Driver behavior on the eastbound approach was videotaped from a location within the public right-of-way, adjacent to the stop bar. Since the filming location was so close to the drivers being studied, a video camera tripod was set within a plastic construction barrel modified with an opening at the top to allow unobstructed filming and to prevent drivers from modifying their behavior due to video surveillance. A camcorder on the tripod within the barrel was used for filming with power supplied from a deep cycle battery. The battery was connected to a power inverter which was attached to a surge protector. The camera was then powered through the surge protector with an AC power cable. A view of the camera location from the traffic barrel is superimposed in FIGURE 20 and shown in more detail in FIGURE 21.

FIGURE 21 “Barrel Camera” Setup.

To record stopping distances accurately, reference dots were painted along the left-turn lane under study. These dots were placed at 1 ft increments from the boundary of the eastbound approach crosswalk to 10 ft beyond the staggered stop line. When analyzing the video, the zero-datum point was the desired stop position, shown in FIGURE 22. The stop line for the left-turning vehicles was faded and worn in places so the line was repainted immediately before beginning the study.

The study was performed on July 14th, 2008 and began at 6:10 am. One observer remained at the study site during filming, a block away from the intersection. During the study, eight different tapes and eight shifts for observation were needed to get an adequate number of observations. The end of taping occurred at 5:30 pm, for a total of 11 hours of video.

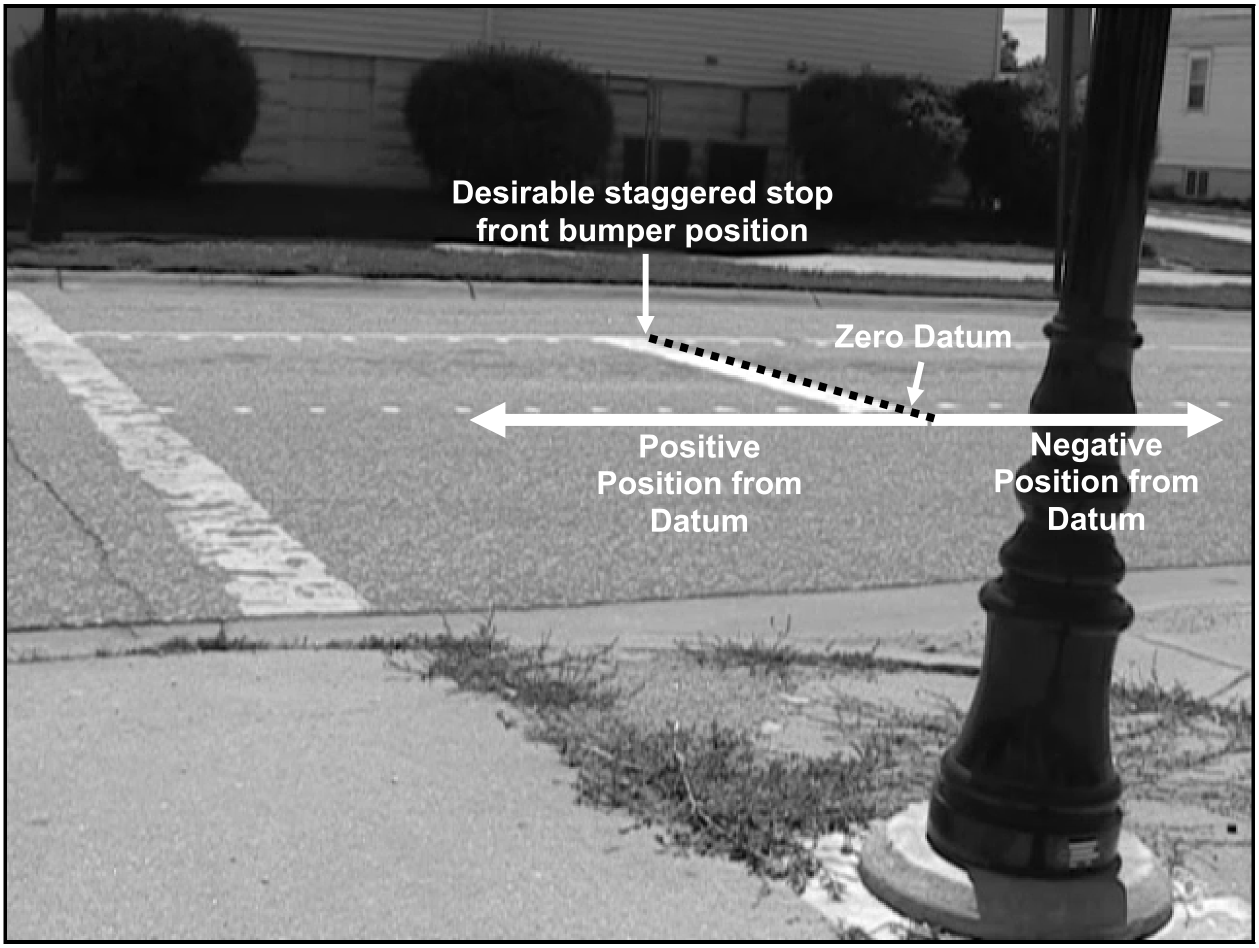


FIGURE 22 Screenshot from Camera Viewpoint with Datum and 1-ft Increment Spaced Reference Dots.

Data Reduction

The videotape was uploaded to digital format. To process the video into quantifiable data, the tape was reduced describing the following conditions:

- Occurrence number,
- Time of occurrence (hour : minute),
- Type of vehicle (passenger car, SUV, Pickup, Minivan or Van, Truck (4 wheels), Truck (6+ wheels)),
- If a right-turn vehicle was present before and after the stop,
- If a large vehicle passed through the intersection heading west on Charleston Street,
- Stop behavior location with respect to the datum line. If the vehicle stopped, and then proceeded further and stopped again, the second stop location was recorded. If a vehicle rolled through the intersection without stopping, the initial point of acceleration was used as the rolling stop position and recorded.

An example of the data sheet used is shown in FIGURE 23.

To quantify the stop position, a screenshot was taken from the video for each stopped left-turn vehicle occurrence. This screenshot was then placed into MicroStation V8 software. The reference dots served as a guideline to place graphics to record the vehicle stop location more accurately. Once finished, the MicroStation V8 drawing was printed out on a transparency without the screenshot. Since the drawing was sized one-to-one, the transparency was placed on the computer monitor with the video playing, and accurate stop positions were compiled.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**Staggered Stop Line Study at 10th and Charleston Sts in Lincoln, NE**														
2	**Monday, July 14th, Filming from 6:30 am to 5:30 pm**														
3	Video Tape 1		Tape Time: 6:10 am to 7:40 am, Cycle Length						Study Site Guard: Dan Carpenter						
4–8	Occurance	Hr-Min	Vehicle Type: Passenger Car	SUV	Pickup	Mini-Van or Van	Truck, 4 Wheels	Truck, 6+ Wheels	Right-Turner Present Before Stop	Right-Turner Present After Stop	Large Vehicle Enters West Leg Before Stop	Large Vehicle Enters West Leg After Stop	First Stop Position	Second Stop Position	Rolling Stop Position
9	1	11:37	1						0	1	0	0	-4.5		
10	2	25:24			1				0	1	0	0	-3		
11	3	26:16			1				0	1	0	0	-5.5		
12	4	29:27	1						0	1	0	0	2.2		
13	5	37:23	1						0	1	0	1	5.9		
14	6	41:10	1						0	0	0	0	12+		
15	7	42:22	1						0	1	0	0	-2.5		
16	8	47:44	1						0	1	0	0	5.5	12+	
17	9	49:34	1						0	0	0	0	12+		
18	10	50:49	1						0	0	0	0	0.2		
19	11	57:09			1				0	0	0	0	-1.5		
20	12	59:50	1						0	1	0	0	5.3		
21	13	1:03:38	1						0	0	0	0	12+		
22	14	1:05:42	1						1	1	0	0	3		
23	15	1:06:23	1						1	1	0	0	4.5		
24	16	1:08:43				1			1	1	0	0	7.2		
25	17	1:10:14	1						0	0	0	0	-0.3		
26	18	1:11:40	1						0	0	0	0			12+
27	19	1:12:38			1				1	1	0	0	-10		
28	20	1:13:32				1			1	1	0	0	12+		
29	21	1:14:29	1						0	0	0	0	12+		
30	22	1:15:35	1						1	1	0	0	-4.7		
31	23	1:16:40	1						1	1	0	0	6.8		
32	24	1:17:33			1				0	1	0	0	1.9		
33	25	1:18:27				1			0	0	0	0	-0.7		

FIGURE 23 Data Sheet for Recording Information from the Video.

FIGURE 24 shows a detailed description of the entry value meaning of each column heading on the first page of the data-reduction spreadsheet.

Column Heading Definitions

Occurance = A left-turning vehicle arrives and stops on the west leg of the intersection.
Hr-Min = The hours and minutes of time that has elapsed from the beginning of the taping session.
Right-Turner Present Before Stop = Is there a vehicle(s) present in the adjacent lane before the left-turn vehicle stops? 0 = No, 1 = Yes
Right-Turner Present After Stop = Is there a vehicle(s) present in the adjacent lane after the left-turn vehicle stops? 0 = No, 1 = Yes
Large Vehicle Enters West Leg Before Stop = Does a vehicle larger than a passenger car enter the west leg from any other approach before the left-turner stops? 0 = No, 1 = Yes
Large Vehicle Enters West Leg After Stop = Does a vehicle larger than a passenger car enter the west leg from any other approach AFTER the left-turner stops? 0 = No, 1 = Yes
First Stop Position = Position of left-turn vehicle when it arrives at intersection and makes one complete stop
Second Stop Position = Position of left-turn vehicle as it makes a second complete stop.
Rolling Stop Position = Position of left-turn vehicle where it significantly accelerates from a slow roll (no complete stop)

Position Definitions:

Desirable Position = Front edge of bumper is directly above the edge of the left-turn stop bar that is furthest from the intersection = 0
Beyond Position = Distance the front edge of bumper is BEYOND the desirable position, estimated to the nearest 0.1 ft = +X.X ft
Before Position = Distance the front edge of bumper is BEFORE the desirable position, estimated to the nearest 0.1 ft = -X.X ft

FIGURE 24 Column Heading Definitions

Stops made before the datum line were recorded as negative values, while stops beyond the datum line were recorded as positive values as shown in FIGURE 25. The boundaries of the stop positions were 10 ft before the staggered stop line and 12 ft beyond the staggered stop line. These were chosen due to the width of the camera view from its field position. Values outside these limits were recorded as “-10+” and “12+,” respectively. Pictures of vehicles stopped at different points along the studied approach are shown in FIGURE 25.

FIGURE 25 Video Screenshots with Stops at 0.0, -3.1, and +10.9 ft from the Datum.

Data Analysis Results
A total of 266 vehicles stopped at a red phase of the traffic signal on the eastbound approach of the intersection during the 11 hours of filming. The position of each stopped vehicle was recorded to the nearest 0.1 ft. Vehicles were categorized in 4 different groups as shown in TABLE 20. No 6-wheel pickup trucks or larger vehicles were recorded as stopping in the left-turn lane of the eastbound approach during the study period.

TABLE 20 Total Number of Vehicles Stopped at Staggered Stop Bar During Study Period

Total Vehicles	Passenger Cars, (P)	Sport Utility Vehicles, (SU)	Pickup Trucks, (T)	Minivans or Vans, (V)
266	147	45	49	25

To obtain the largest sample sizes of drivers in similar driving environments, occurrences were divided further into 3 types of conditions:

Condition 1: The EB to NB driver stopped when no other vehicles were turning into or out of the west leg of the intersection. In this situation, the driver's final stopped position was not influenced by surrounding vehicles on the study approach.

Condition 2: There was a through/right-turning vehicle in the adjacent EB through/right lane before or after the driver stopped. The fact that an adjacent vehicle was present may have influenced the final stopping position of the driver.

Condition 3: There was a vehicle turning into the westbound lane on the west approach before or after the driver stopped. Since the purpose of the staggered point line is to allow turning vehicles to avoid conflicts with those stopped, a turning vehicle may have influenced the final stopped position of the driver.

FIGURE 26 shows the percent occurrence frequency of the location of the front edge of the front bumper of the stopped vehicles recorded. After viewing the results, it was apparent that once drivers got beyond a certain point, their view of the staggered stop bar would not be possible and their positioning would then be influenced by the near edge of the crosswalk instead (essentially a second stop-bar location). Recognizing this effect, an assumption was made that the eye of the driver was 8 ft behind the front edge of the front bumper of the vehicle (as used in the intersection sight distance model of the AASHTO Green Book (28, page 657)). Once the bumper was 8 ft beyond the datum line (a recording of +8.0 ft), the staggered stop line was assumed to have no influence (i.e. the driver could no longer see the staggered stop bar without turning his/her head 90 degrees and looking down at the pavement).

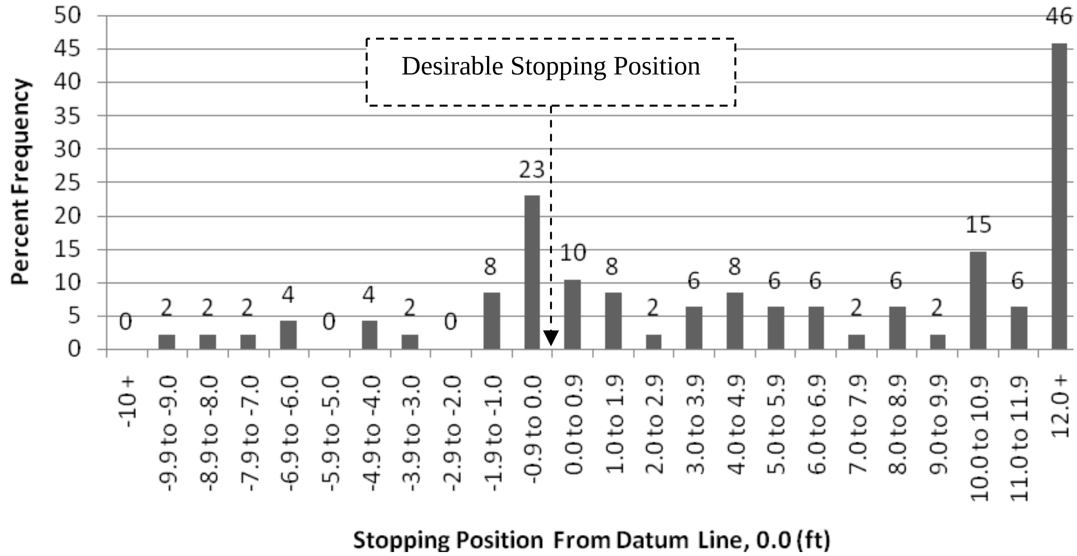


FIGURE 26 Percent Occurrence Frequency of Front Bumper Position Under Condition 1 with Total Number of Vehicle Occurrences from Study.

The data was then reduced to eliminate all occurrences of +8.0 ft or more. This resulted in the sample of vehicles shown in TABLE 21.

TABLE 21 Vehicles Stopped at Staggered Stop Bar During Study Period That Were Within 8 Ft (Position of +8.0 or Less) Beyond the Staggered Stop Bar

Total Vehicles	Passenger Cars, (P)	Sport Utility Vehicles, (SU)	Pickup Trucks, (T)	Minivans or Vans, (V)
190	105	32	36	17

FIGURE 27 shows the percent occurrence frequency of this subgroup of vehicles under Condition 1. Conditions 2 and 3 are shown in FIGURES 28 and 29 respectively. FIGURE 30 shows the percent occurrence frequency for all conditions combined. TABLE 22 shows a summary of statistics for the data along with sample size error estimates.

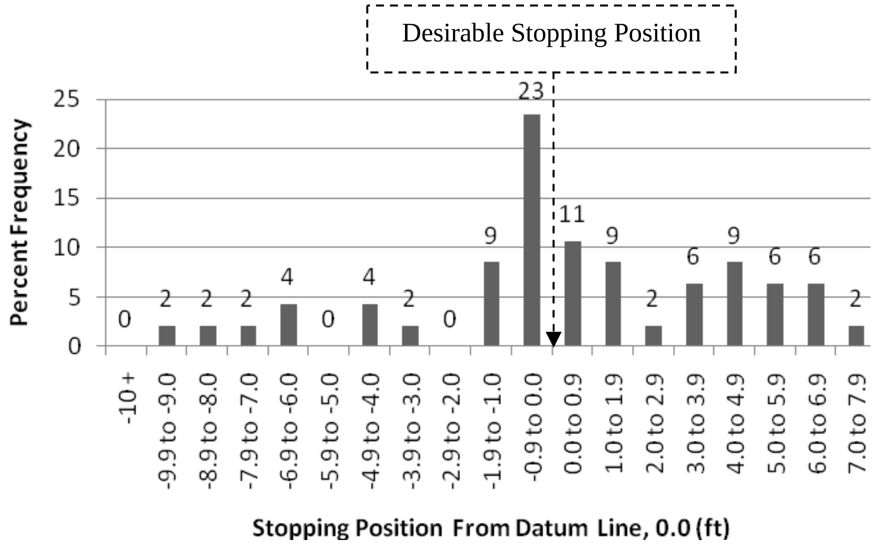


FIGURE 27 Percent Frequency of Positioning, Condition 1.

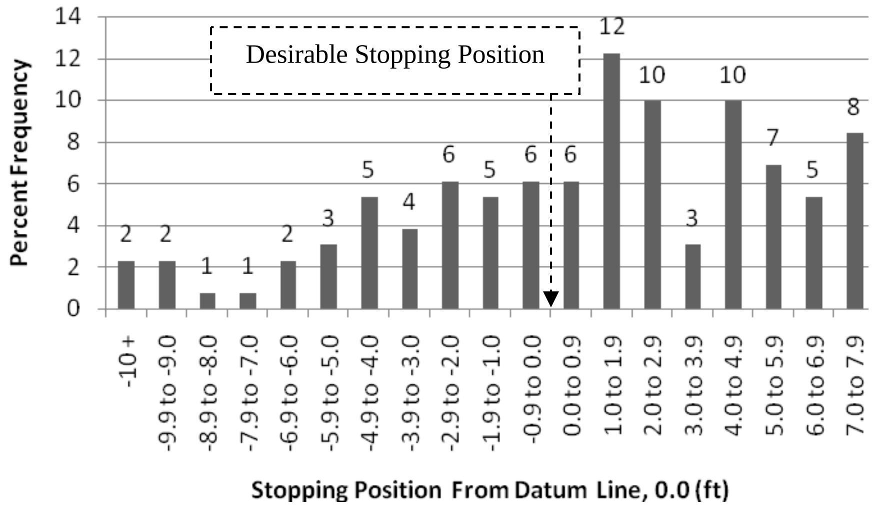


FIGURE 28 Percent Frequency of Positioning, Condition 2.

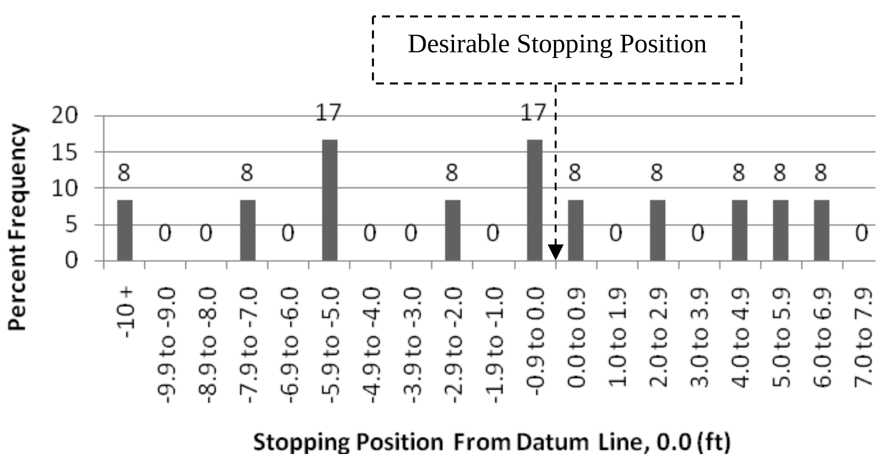


FIGURE 29 Percent Frequency of Positioning, Condition 3.

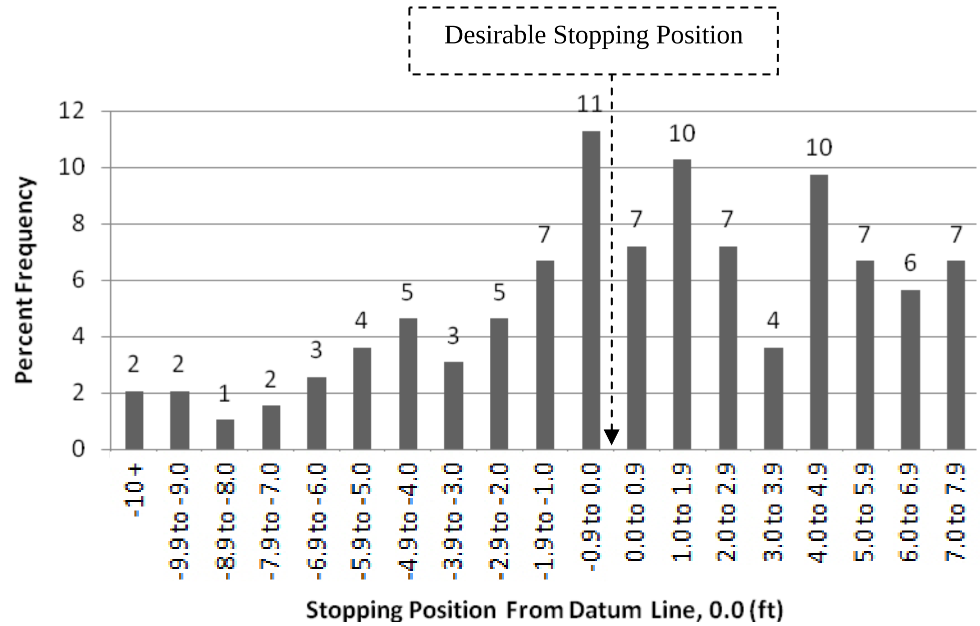


FIGURE 30 Percent Frequency of Positioning, Conditions 1, 2, and 3 Combined.

TABLE 22 Statistics for All Condition Groups

Cond	Sample Size, Vehicles					Mean, ft	Error, ft	Median, ft	Mode, ft	Std Dev, ft	85^{th}-%tile, ft	Sample Size Error, ft	95^{th}-%tile, ft	Sample Size Error, ft
	Total	P	SU	T	V									
1	47 Total	26	7	9	5	+0.5	±1.2	+0.2	-0.3	+4.1	+4.6	±2.5	+6.8	±3.0
2	111 Total	73	24	9	5	+0.9	±0.8	+1.8	+1.8	+4.5	+5.8	±1.7	+7.2	±2.0
3	12 Total	6	1	3	2	-1.0	NA	-0.5	NA	+5.0	+4.7	NA	+6.4	NA
1,2,3	170 Total	105	32	21	12	+0.6	±0.7	+0.9	+1.8	+4.5	+5.6	±0.8	+7.1	±0.9

FIGURE 31 shows a visual interpretation of the confidence range of the 85-percentile position of vehicles for Condition 2 (shaded values in TABLE 22). This means that considering the least error, 85 percent of stopping drivers under Condition 2 positioned their vehicles at +4.1 ft or less from the desired position. Considering the most error, 85 percent of stopping drivers under Condition 2 positioned their vehicles at +7.5 ft or less from the desired position. FIGURE 28 also shows that 40 percent of the stopped drivers studied under Condition 2 did so at or before the desired location. Half of the stopped drivers (the median value shaded in TABLE 23) positioned their vehicles +1.8 ft or before the desired position.

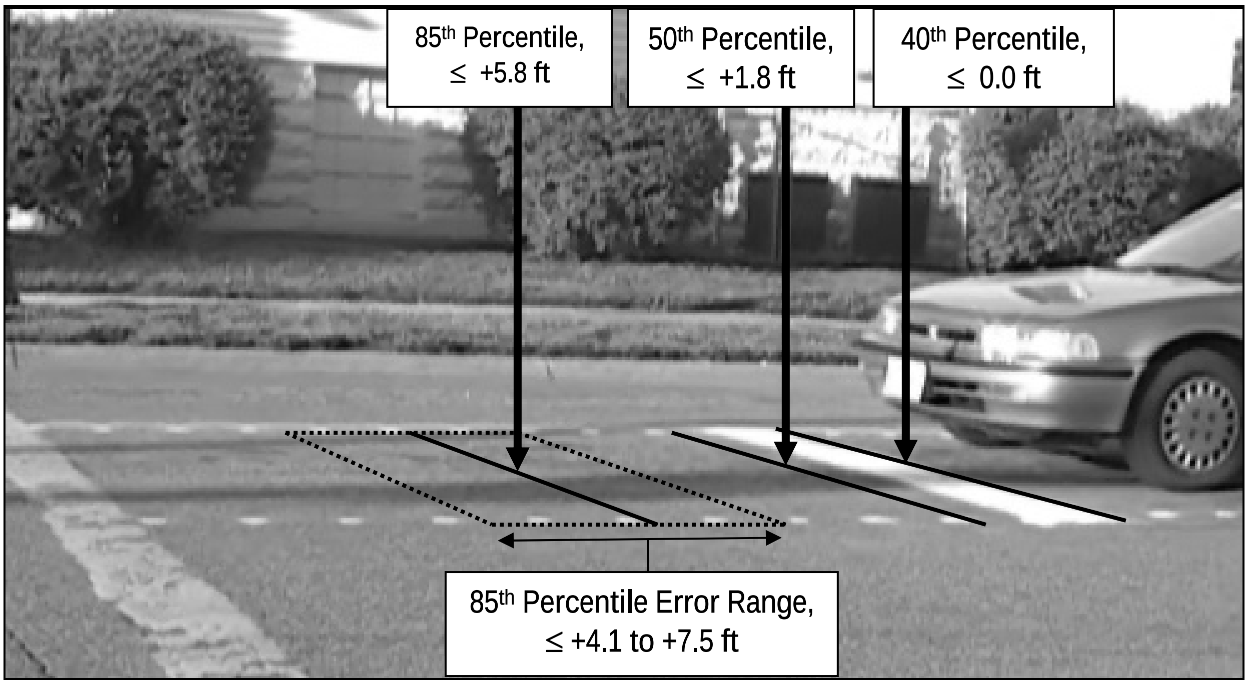


FIGURE 31 Visual Interpretation of Staggered Stop Bar Driver Behavior Results

Conclusions from Staggered Stop Bar Field Study

The results of the field observation study verify that drivers generally perceive and react to painted stop bars. About half of drivers under Condition 1 exhibited desirable behavior by stopping at or before the staggered stop line. Conditions 2 and 3 are most like those that will occur at critical sight distance situations on multiple approach lanes since Condition 1 would reflect views of the intersection that are unobstructed by adjacent vehicles. The largest subgroup, Condition 2, yields the best estimate of how drivers are likely to behave during critical sight distance situations at staggered stop bar locations with 2-way stop control. Half of this subgroup stopped at +1.8 ft beyond the staggered stop bar or before and 85 percent of this group stopped at or before +5.8 ft. Considering the 95^{th}-percentile level of confidence error due to sample size, 85 percent of drivers would most likely stop between +7.5 and +4.1 ft or before the desirable location, under similar conditions.

Inferences from Results of the Staggered Stop Bar Field Study

Since the study data was compiled in the daylight during sunny conditions, all drivers approaching the staggered stop bar had the opportunity to see it and the crosswalk lines at the approach since they were both in relatively good condition. Obviously, their choice of exactly where to stop their vehicles with respect to those lines varied widely. This may suggest that drivers are generally unsure of exactly where to position their vehicles when confronted with a white transverse paint line within their driving lane. This indicates a need to present better guidance about vehicle positioning with respect to stop bar locations in the Nebraska Driver's Manual.

Stopping Guidance for Nebraska Drivers

The Nebraska Driver's Manual(29, 2008) and the Manual on Uniform Traffic Control Devices (7, MUTCD, 2003) states that in the presence of a stop sign a driver must come to a complete stop before entering an intersection. If there is a painted stop line present, the driver is to stop at the line. FIGURE 32 shows the information that is provided to the driver in the driver's manual (30, 2008).

Stop Lines

Stop lines are white lines painted across the pavement at intersections indicating the position to stop. In urban areas, the line is usually located about four feet before a crosswalk. **Drivers must stop at the line** (when present), not at the stop sign or traffic control signal.

Crosswalk Markings

These lines are painted across or partially across the pavement. Pedestrians have the right of way when pedestrians are in these crosswalks. Crosswalks are sometimes in the middle of the block in residential areas and school areas. Crosswalk areas may also be unpainted.

FIGURE 32 2008 Nebraska Driver's Manual Quote Referring to Stop Lines and Crosswalk Markings, Section 3C-4, page 40
http://www.dmv.state.ne.us/examining/pdf/engdrivermanual.pdf

Limitations of the Staggered Stop Bar Study

Due to the fact that no 2-way stop-controlled intersections with staggered stop bars were available for study in the regional area, drivers at a signal-controlled intersection with a staggered stop bar on one approach were studied to estimate how compliant drivers are with stopping at a desired location based on this type of white transverse stop line pavement marking installation. Inferences were drawn from the resulting behaviors to indicate that using a staggered stop bar at multiple lane approaches to influence left-turning drivers to stop further from the cross-traffic lane than right-turning drivers would result in a positive outcome. A further recommendation is to do a before-and-after study using the proposed signing combination to see if the inferences are correct before final approval is confirmed by traffic authorities.

Recommendations to Improve Driver Compliance with Desirable Positioning of Their Vehicles at Stop Bar Locations.

Since the written guidance given is vague and there are no illustrations showing the correct position at which the vehicle should be located with respect to the stop line, adding an illustration to the manual may improve driver compliance with the position traffic authorities believe to be desirable.

It would also be beneficial to have written guidance and an illustration of desirable positioning at the physical location of the stop bar since that is where the information is most useful.

The State of Nebraska currently has a special placard designed which is to be placed immediately above or below the stop sign at a stop-controlled intersection to encourage drivers to recognize the desirable position for them to stop their vehicles. FIGURE 33 shows an example of the "STOP AT LINE" placard (NDOR Sign R1-5C-24).

FIGURE 33 Example of NDOR Sign R1-5C-24.

The legal definition of a stop is available in the Lincoln Municipal Code. It reads "Stop, when such act is required, shall mean complete cessation of movement" (31, Lincoln Municiple Code, 2008). The regulations governing a vehicle entering a stop controlled intersection are as follows:

"(a) Except when directed to proceed by a police officer or traffic-control signal, every driver of a vehicle approaching a stop intersection indicated by a stop sign shall stop before entering the crosswalk on the near side of the intersection, or in the event there is no crosswalk, shall stop at a clearly marked stop line, but if none, then at the point nearest the intersecting street where the driver has a view of approaching traffic on the intersecting street before entering the intersection.

(b) Such driver, after having stopped shall yield the right-of-way to any vehicle which has entered the intersection from another street or which is approaching so closely on said street as to constitute an immediate hazard, but said driver having so yielded may proceed and the drivers of all other vehicles approaching the intersection shall yield the right-of-way to the vehicle so proceeding".

Thus a sign reading "STOP AT LINE" will not conflict with the letter of the law.

If a "STOP AT LINE" sign were added to the same support post that the STOP sign and DIVIDED HIGHWAY sign are mounted upon, some may argue that too many signs on the same support would be confusing for the driver. The MUTCD states that “signs should be individually installed on separate posts or mountings except where one sign supplements another” (7, 2003, Section 2A.16.A). Three signs may require two mounting posts rather than one as shown in the circled area within FIGURE 37 which is a reproduction of the STOP sign installation in Figure 2B-14 of the MUTCD (7, 2003, page 2B-34).

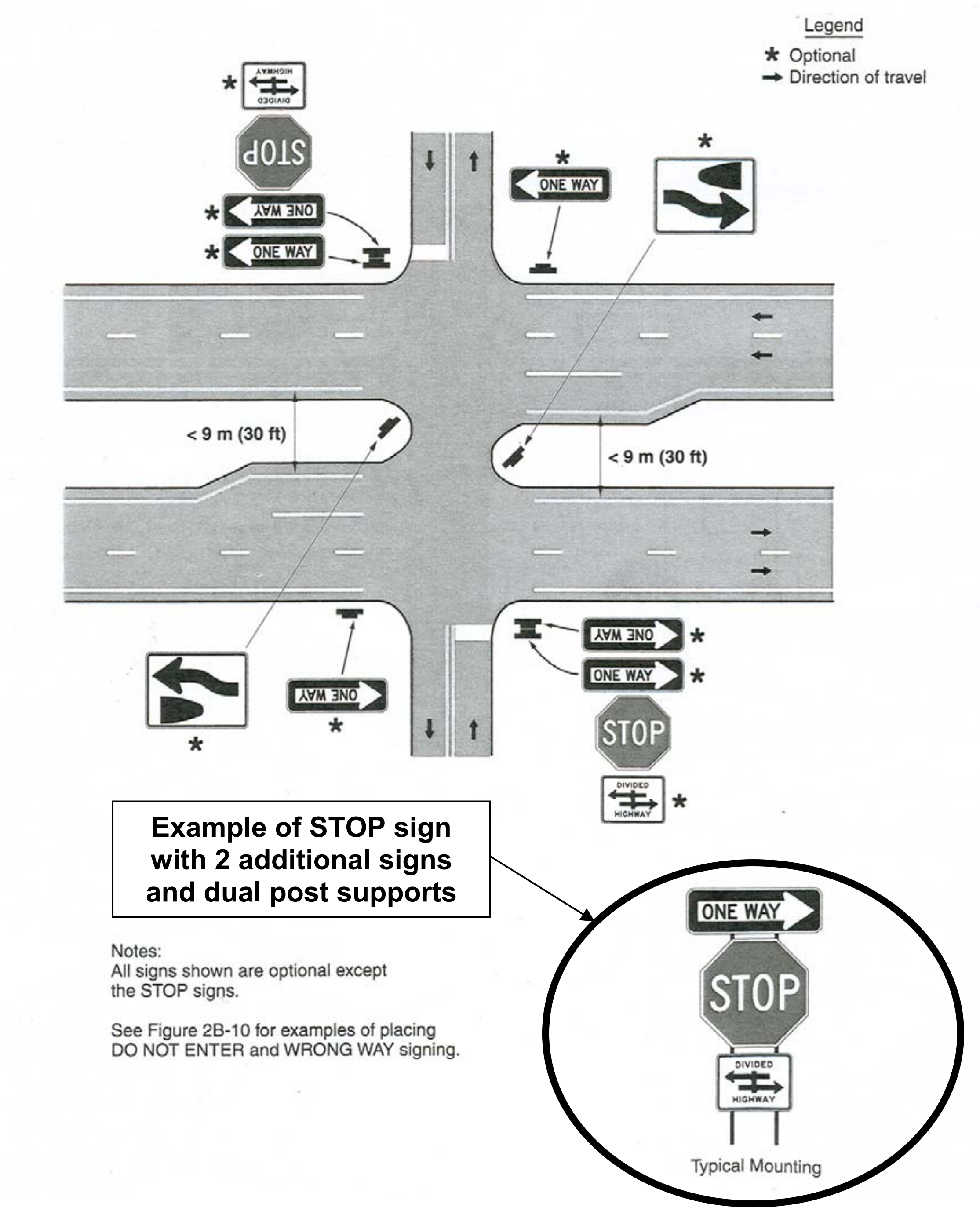


FIGURE 34 Reproduction of Figure 2B-14 of the MUTCD

Effectiveness of Adding "Stop at Line" Sign

In the ORTL study *"Conditions Warranting Offset Right-Turn Lanes (ORTL) for Improved Intersection Sight Distance"*, (NDOR Project SPR-P1(06)P592), the "Stop at Line" sign was added only to the STOP sign on the right side of the approach, instead of on both STOP signs. This was due to the fact that the center median STOP sign already had a divided median sign (required) and a diamond-shaped delineator sign (optional) on a single post. NDOR signing authorities felt adding another sign to this existing combination would violate engineering judgment principles based on minimizing the number of sign messages per installation. A photograph of the final study sign installation is shown in FIGURE 35.

FIGURE 35 Example of Placement of STOP AT LINE Sign Only on Right STOP Sign on ORTL Project

Both locations exhibited driver stopping behavior that was not conducive for optimal intersection sight distance, given the fact that right-turning traffic within either style of right-turn lane would temporarily block the view of drivers judging suitable gaps in cross traffic for a safe entry into the intersection. Stopping position data was collected to see if adding the "STOP AT LINE" sign under the STOP sign on the right side of the approach would encourage drivers to locate their vehicles at the desirable position where stop bars were positioned, which is 6 ft from the edge of the cross traffic lane, as shown in FIGURES 36 and 37.

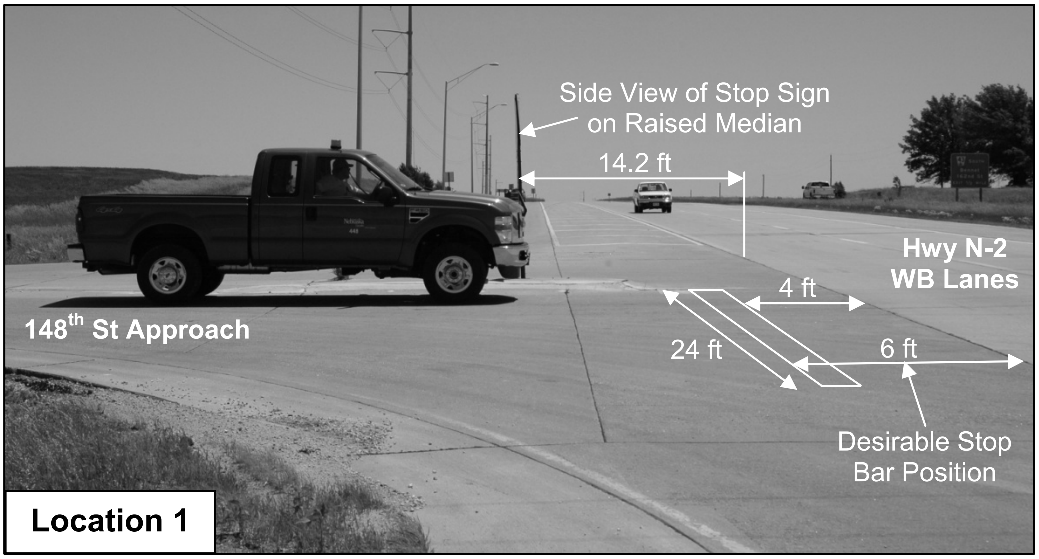


FIGURE 36 Painted Stop Bar at Desirable Location for Optimal Intersection Sight Distance for Stopped Driver at 148th and Hwy N-2 Intersection

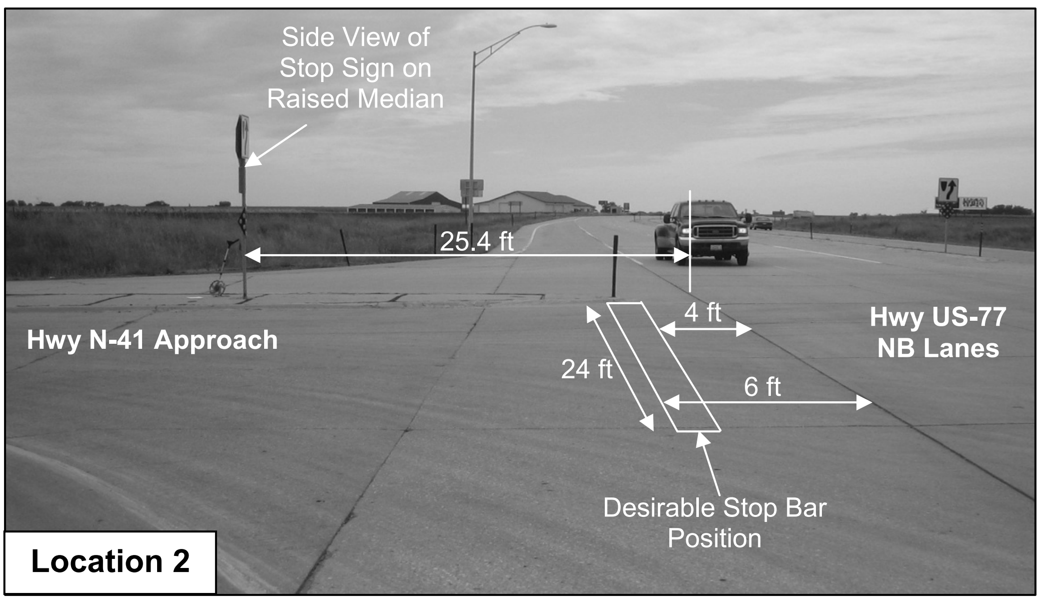


FIGURE 37 Painted Stop Bar at Desirable Location for Optimal Intersection Sight Distance for Stopped Driver at Hwy US-77 and N-41 Intersection

Study Methodology

As describe previously, data was collected at Locations 1 and 2 under three scenarios:

- **Scenario 1 - BEFORE** was before anything was changed at the intersection. Stop bars at both locations were “freshened” before any information was collected to make sure that they were in the best condition possible to be viewed by drivers. Data was collected for a period of five consecutive 12-hour days to ensure that enough stopped vehicles were recorded for a statistically significant interpretation of the results.

- **Scenario 2 - AFTER** involved collecting video for five consecutive 12-hour days one week after the installation of the "STOP AT LINE" sign. The week delay was to make sure drivers were acclimated to the modified sign.
- **Scenario 3 – EXTENDED STUDY (or ES)** included five consecutive 12-hour videos of driver stopping behaviors 4 weeks after the "STOP AT LINE" sign was installed to determine if the sign had a diminishing effect over time.

Results of Adding "STOP AT LINE" Sign to STOP Sign on Right Side of Approach
TABLE 23 shows the results of the data collected for all three scenarios.

TABLE 23 Vehicle Position Results from ORTL Study

Measure	Location 1 – 148th & N2			Location 2 – US77 & N41		
	Scenario 1 Stopping Position	Scenario 2 Stopping Position	Scenario 3 Stopping Position	Scenario 1 Stopping Position	Scenario 2 Stopping Position	Scenario 3 Stopping Position
Veh Count	1062	735	918	443	283	194
Mean, ft	16.2	16.4	15.4	17.2	17.1	17.1
Median, ft	15.1	15.6	14.6	16.7	16.2	16.1
Std Dev, ft	6.5	6.7	6.2	8.8	8.4	9.3

Although Location 1 showed a slight improvement in driver stopping behavior over the extended period of time for Scenario 3, it was only about 1 ft in magnitude which would not generally improve the driver's intersection sight distance if a right-turning vehicle were in the right-turn lane. Looking at FIGURES 36, 37 and 38 allows one to speculate on reasons for the relative failure of the "STOP AT LINE" sign to make a difference in driver positioning behavior. FIGURE 38 shows examples of visual cues the minor road approach driver may be receiving from the three-dimensional features and traffic control devices at the intersection which may be resulting in inappropriate choices for optimal safety. Recommendations for improving the misleading visual cues are shown in FIGURE 39. Each visual cue issue, recommendation for improvement, explanation of recommendation and official guideline resource is summarized following FIGURES 38 and 39 in TABLE 22. FIGURE 40 shows a plan view of the proposed recommendations.

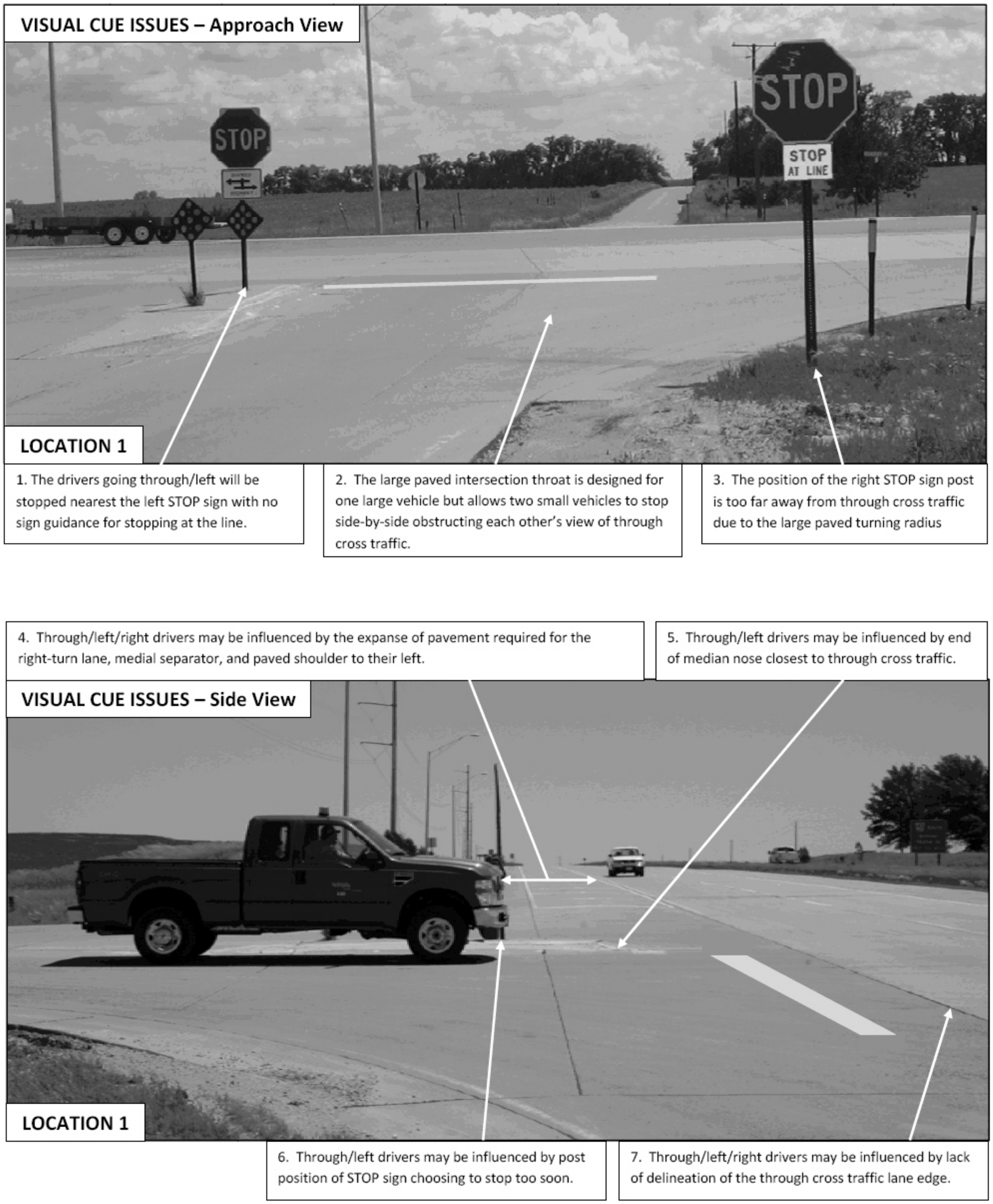


FIGURE 38 Counter-productive Visual Cue Issues at Location 1, ORTL Study

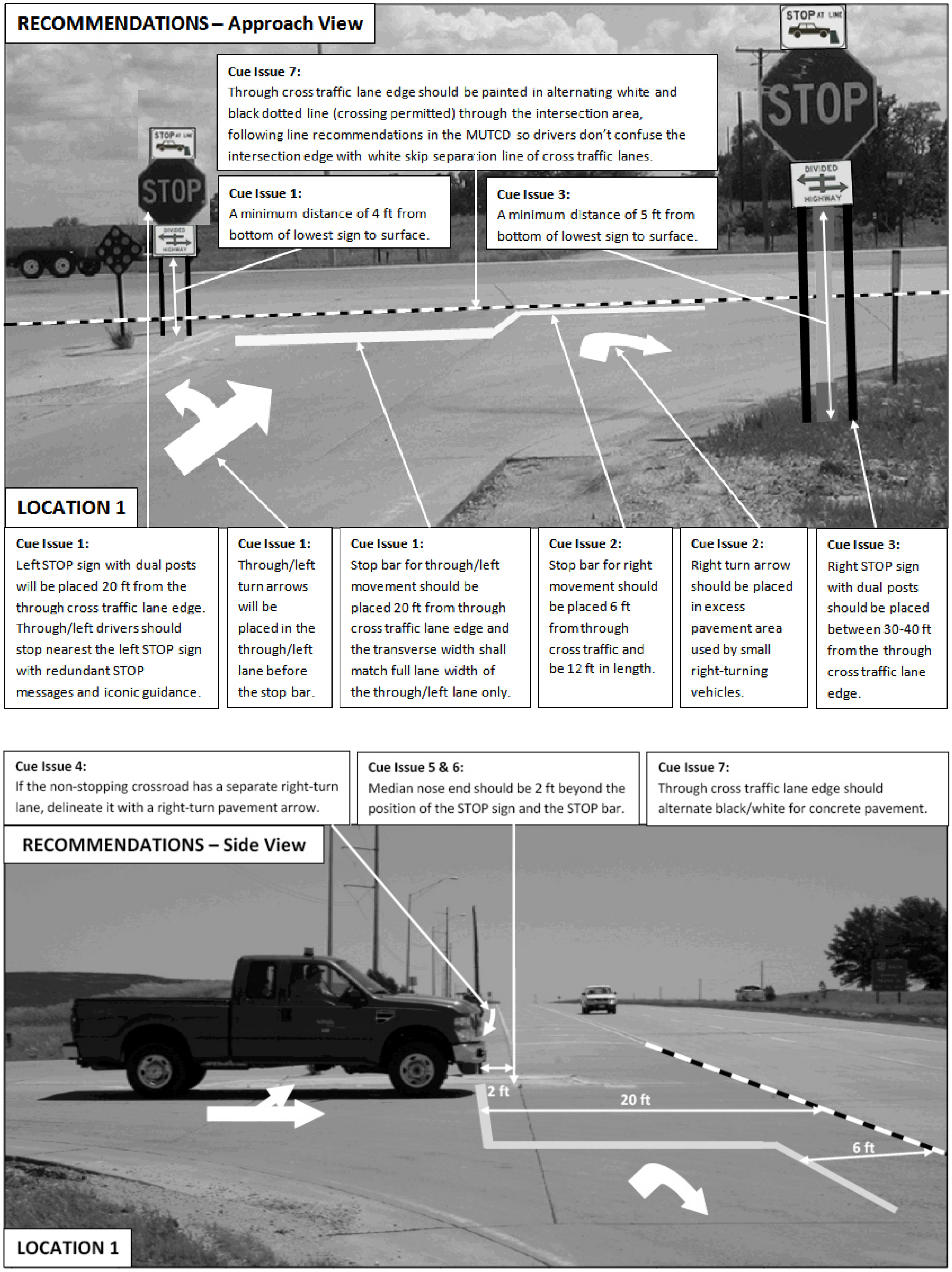


FIGURE 39 Improvements of Visual Cues at LOCATION 1, ORTL Study

TABLE 24 Summary of Visual Cues and Recommendations for Improvements

Issue No.	Inappropriate Visual Cue	Recommendation for Improvement	Explanation	Applicable Guidelines
1	Through/left drivers on the minor road approach may stop at the left-side stop sign with no indication that the desirable position is actually closer to the through cross traffic lane edge.	Place left STOP sign (dual posts) 20 ft from the through cross traffic lane edge. Include text-icon version of STOP AT LINE sign above STOP sign and if the major cross road is a divided highway, include DIVIDED HIGHWAY sign below STOP sign. Ensure that the bottom of the lowest sign is no closer than 4 ft to the surface below the sign. Add stop bar 20 ft from through cross traffic lane edge for the width of the through/left approach lane. Include through/left arrow on pavement of through/left approach lane.	Multiple signs at a single installation are allowed if the signs supplement each other. Through/left minor road approach traffic position will allow good ISD for right-turn driver. View of T/L driver will be minimally blocked by right-turn vehicle. It is nearly impossible for a through/left vehicle to be struck by cross traffic from the right that may be visually blocked by a right-turning vehicle.	MUTCD Section 2A.16.A, C MUTCD Figure 2A-1, page 2A-9 MUTCD Section 3B.16
2	Approach pavement throat must be constructed for large vehicle turning paths. Two small vehicles can fit side-by-side inhibiting each others' view of cross traffic gaps.	Add a second stop line 6 ft from the through cross traffic lane edge for a 12 ft width. Connect both stop bars with a single white solid line. A right-turn pavement arrow should be added before the right stop bar.	If the paved intersection throat area is large, it is possible for two small vehicles to be side-by-side. It is likely that a right-turning driver would angle the small vehicle toward the right in the paved area available according to a priori expectancy and minimally restrict a through /left driver's view of approaching major road vehicles from the right.	2004 AASHTO Green Book, pages 583-621
3	Position of right-side STOP sign is not adjacent to desirable stopping position of right-turning drivers due to the large paved turning radius.	Place right stop sign (dual posts) 12 ft minimum to 50 ft maximum from the through cross traffic lane edge. Include text-icon version of STOP AT LINE sign above STOP sign and if the cross road is a divided highway, include DIVIDED HIGHWAY sign below the STOP sign. Ensure that the bottom of the lowest sign is not less than 5 ft higher than the elevation of the paved edge of the approach lane closest to the post.	A paved intersection designed for a large vehicle exhibits a large turning radius that prevents the STOP sign on the right side from being close to the through cross traffic lane edge.	MUTCD Section 2A.16.A, C MUTCD Section 2A.18
4	Extra width for right-turn lanes, medial separators, and paved shoulders may confuse minor road approach drivers' idea of where the through cross traffic lane edge is located	If there is separate right turn lane on the major road to the left of the driver stopped on the approach, include a right-turn painted arrow in the right-turn lane in clear view of the stopped driver to enable recognition of the purpose for extra paved lanes. Minimize paved shoulder width on the right-turn lane.	It is necessary for the driver of a stopped vehicle on the minor road approach to appropriately judge the position of the major road through cross traffic lane edge to feel safe when the vehicle is at rest. Concrete pavement on a sunny day reflects light which diminishes the ability to discern lane lines, added lanes, medial separators and shoulders. Any acceptable method to better delineate these features for what they are is recommended.	MUTCD Section 3B-19
5	The raised median nose must be at least a shoulder's width from the through cross traffic edge of pavement and therefore may indicate that moving closer to the lane edge is inappropriate.	The end of the median nose closest to the major road should be 2 ft beyond the dual posts of the STOP sign (18 ft from the through cross traffic lane edge).	It is important that the left STOP sign posts, median nose end and stop bar are all in the same position to redundantly remind the driver to stop where it is desirable for the given situation. Locating a raised median nose 18 ft from the through cross traffic lane edge should not violate AASHTO guidelines for clear shoulder widths along roadways.	2004 AASHTO Green Book, pages 312-315
6	Desirable stopping position is not adjacent to left-side STOP sign post position on approach.	The left STOP sign should be positioned exactly where the desirable vehicle stopping position is located since the sign itself will be readily visible on the driver's side of the vehicle, at the driver's eye height and above. This position is 20 ft from the through cross traffic lane edge.	It is most critical that the driver in the through/left lane position the vehicle properly, since this particular movement is of the lowest priority in the intersection traffic movement hierarchy. The right-turning driver will likely angle the vehicle slightly and roll forward while assessing traffic gaps from the left.	2000 HCM Page 17-4 MUTCD Figure 2A-2, page 2A-10
7	Through/left/right drivers on the minor road may be influenced by confusion of the exact location of the through cross traffic lane edge since the pavement surfacing is all one color.	The though cross traffic lane edge should be delineated by an alternate white/black dotted line. The black dot alternate is for situations with concrete pavement and added auxiliary lanes where it is difficult to judge the lane edge.	As mentioned in Issue 4, it is necessary for the driver of a stopped vehicle on the minor road approach to appropriately judge the position of the major road through cross traffic lane edge to feel safe when the vehicle is at rest. Adding the pavement marking delineation is intended to avoid confusion of visualizing the lane edge correctly.	MUTCD Section 3B.06, 3B.008, pages 3B-16 to 3B-19

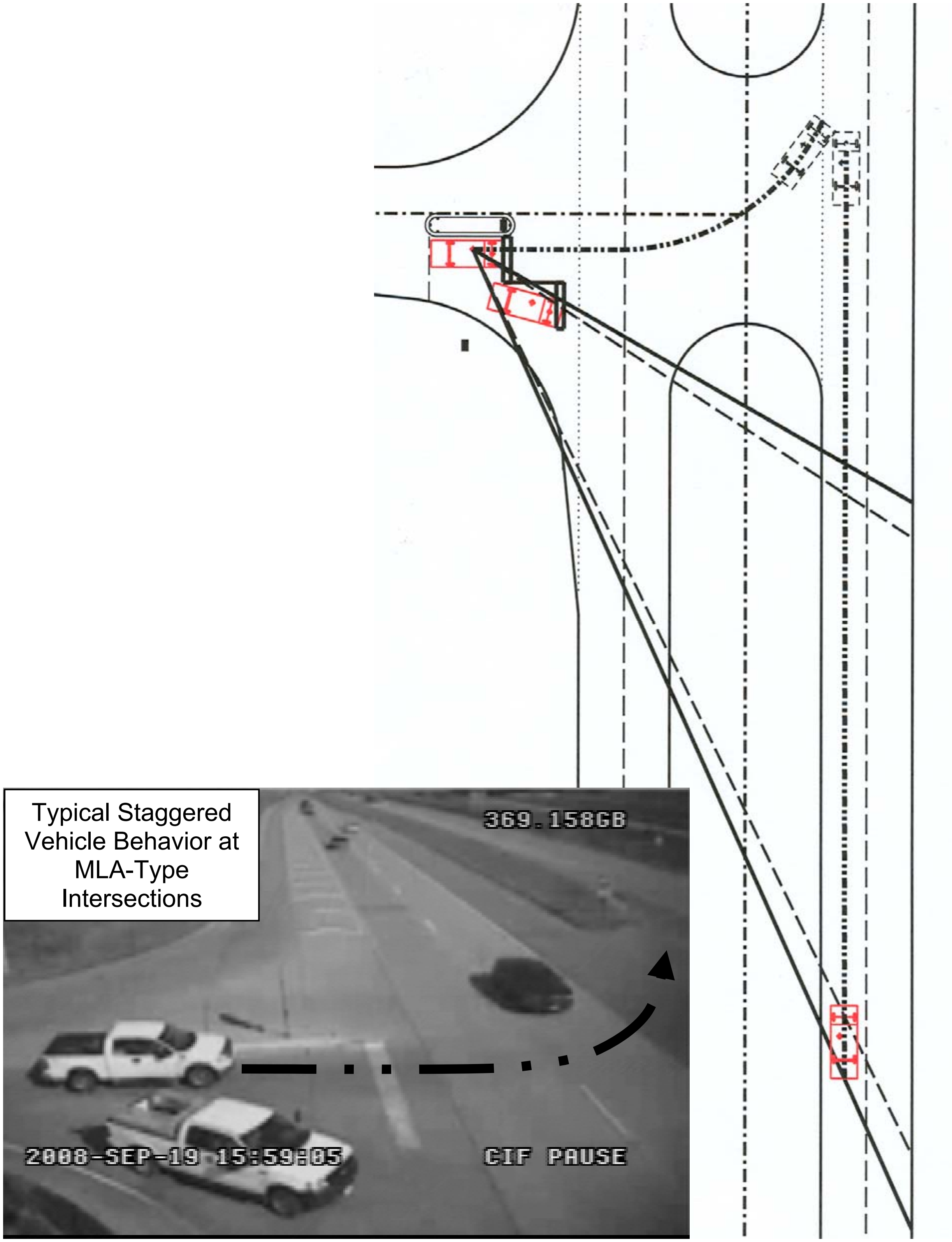


FIGURE 40 Plan View of Proposed Staggered Stop Bar Pavement Marking to Better Fit Driver Behavior at MLA-Type Intersections

Effect of MLA Approach Stop Bar Location on Through Traffic

It is possible that locating the MLA approach stop bar between 4 and 6 feet from the through lane of high-speed traffic could influence through drivers to veer away from stopped vehicles waiting to turn. To assess the potential of this behavior, the ORTL video was viewed again for this purpose.

FIGURE 41 shows a situation of a left-turning driver positioned correctly at the stop bar at the US 77 and N-41 study location. The stop bar is 2 feet wide and is located from 4 ft to 6 ft away from the edge of the through traffic lane. Transparent plastic with a calibrated distance measuring scale was taped to the monitor while the video was played to estimate the position of the near tire with the pavement edge (which was the most legible interface due to the video picture quality). All occurrences of left-turning approach vehicles less than or equal to 6 ft from the through lane edge on the available videos were viewed and positions of through vehicles were recorded. A similar number of recordings were made of vehicle positioning when there were no left-turning vehicles present at the stop-controlled approach. Results of the findings are shown in FIGURE 42.

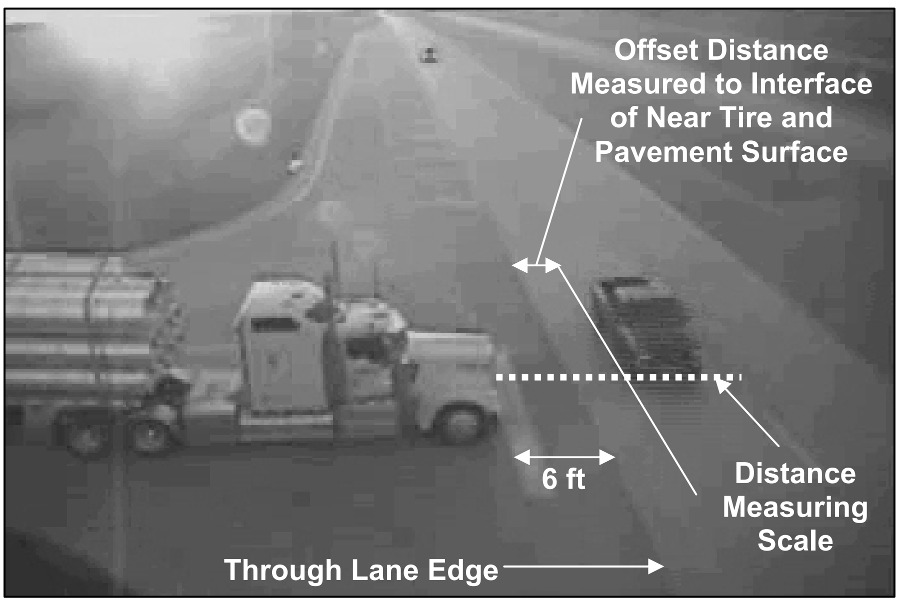
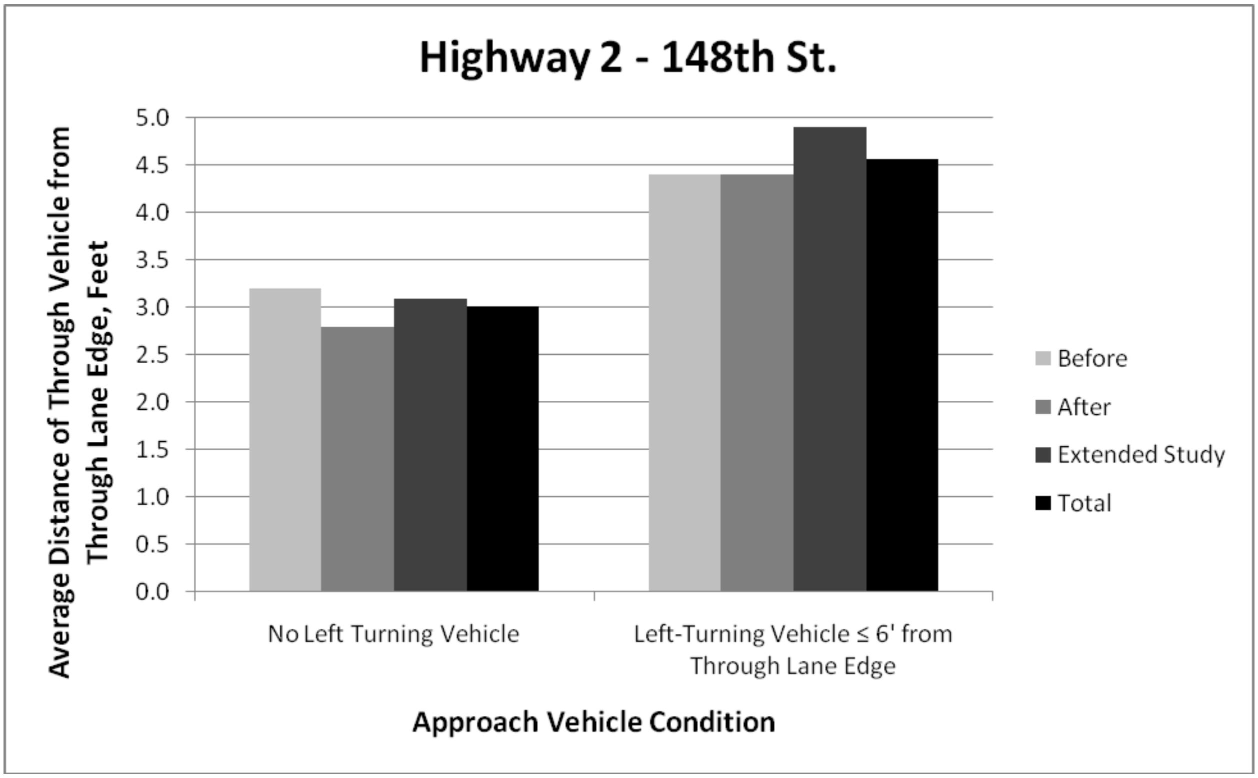


FIGURE 41 Example of Determination of Through Vehicle Positioning at US 77 and N-41 Intersection



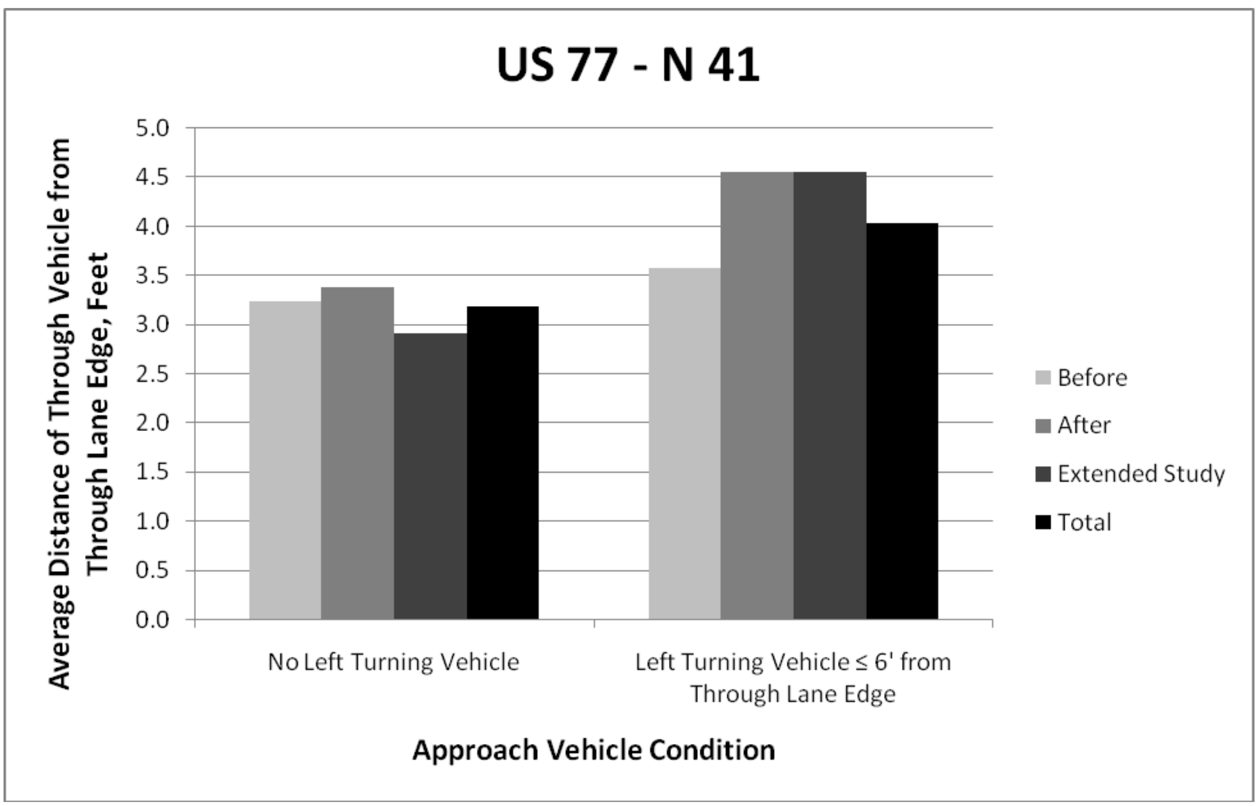
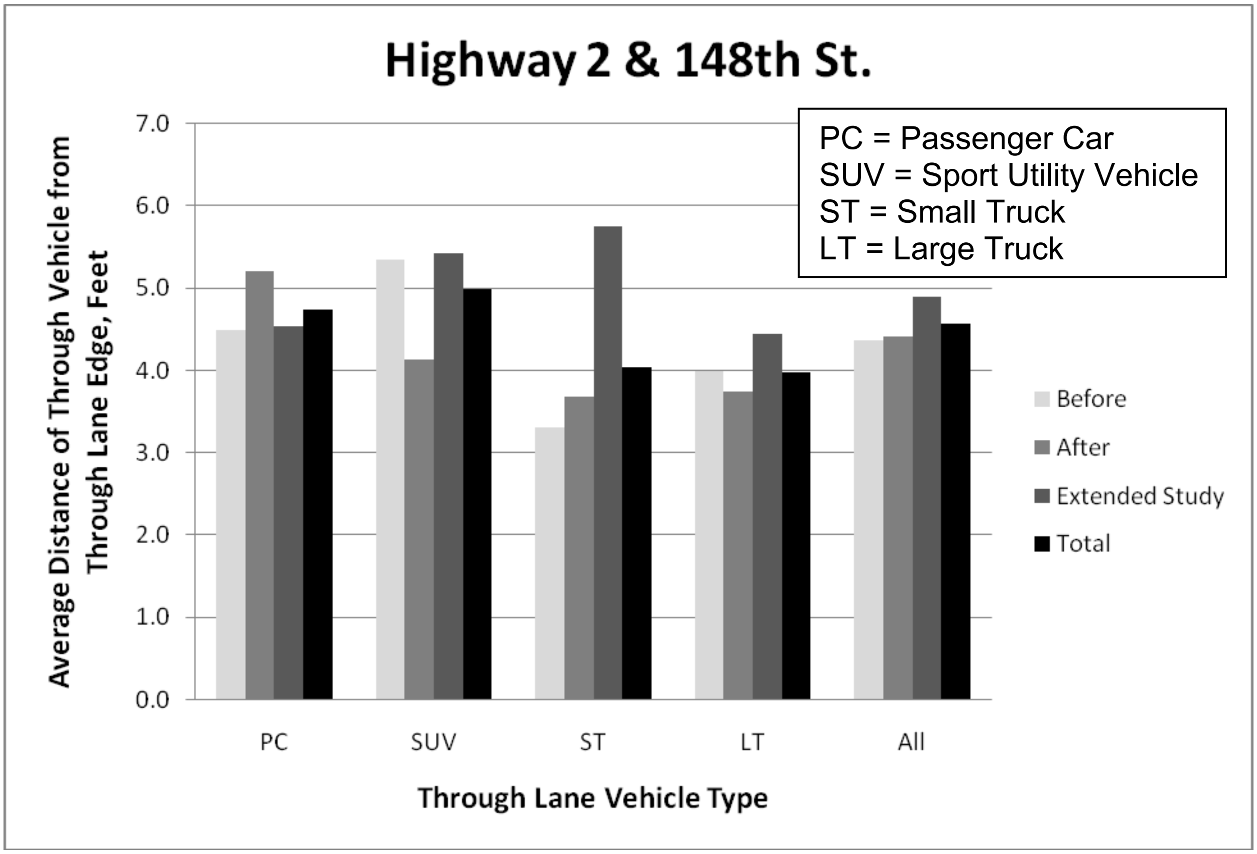


FIGURE 42 Comparison of Through Vehicle Lane Positioning When Stop-Controlled Approach Vehicles At or Within 6 ft of Through Lane Edge and When No Approach Vehicles are Present

Results of the study show that drivers tend to veer about 1 ft further away from the through lane edge when stop-controlled approach vehicles are present within 6 ft of the through lane. The near tire and pavement position of vehicles was generally 3 ft from the through lane edge when no vehicle was present as opposed to 4 ft when a vehicle was present at the stop bar location or nearer. Veering of drivers in the through lane may cause a safety problem with through vehicles in the adjacent major road lane, especially if the veering vehicle is a large truck. Veering vehicles were categorized by vehicle type to better understand if this behavior may be an issue. Results are shown in FIGURE 43.

Both small and large trucks tend to veer less than smaller vehicles like passenger cars and sport utility vehicles, indicating that the drivers of larger vehicles may be aware that veering within their lane make cause safety problems with respect to traffic in the adjacent through lane.



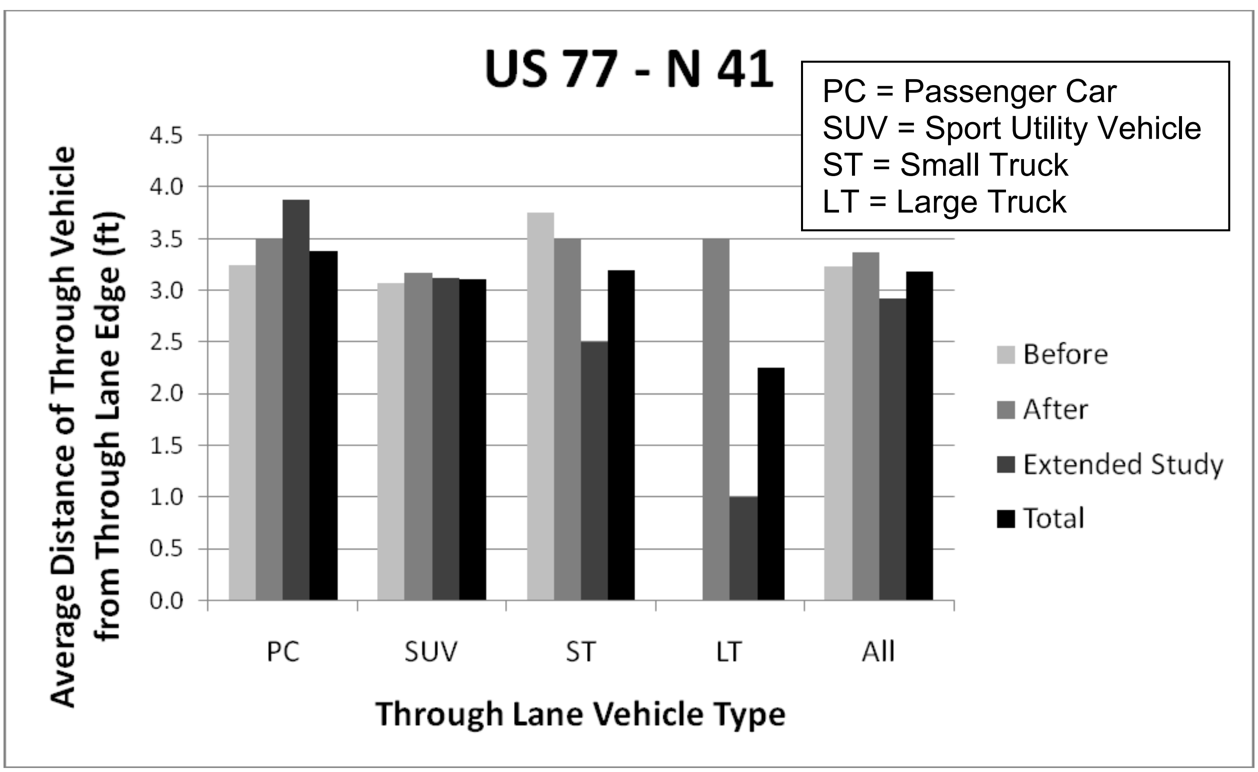


FIGURE 43 Comparison of Through Lane Vehicle Type Positioning When Stop-Controlled Approach Vehicles At or Within 6 ft of Through Lane Edge

Introduction of Icon-Style STOP AT LINE Sign

Due to the results of the staggered stop bar study and the ORTL study, it may be beneficial to also include an iconic placard, in place of or in conjunction with the STOP AT LINE sign. Examples of how the signs could look are shown in FIGURES 44 and 45.

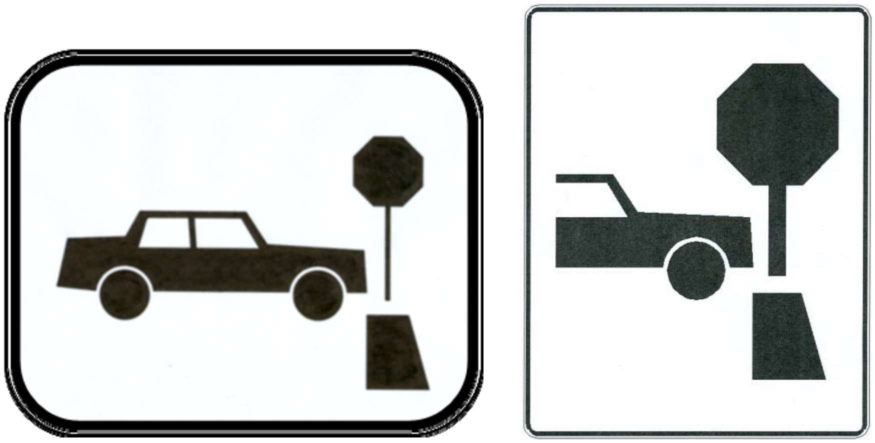


FIGURE 44 Examples of Iconic "STOP AT LINE" Placard

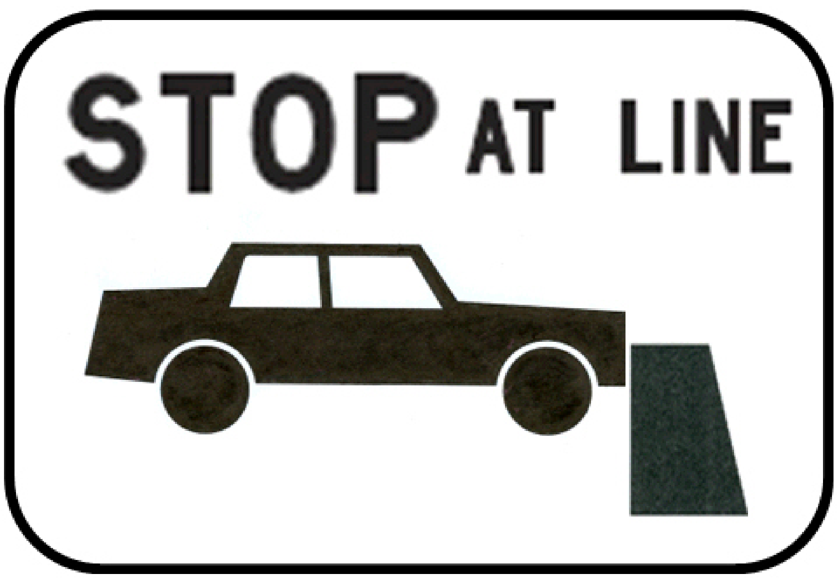


FIGURE 45 Example of "STOP AT LINE" Sign and Iconic Placard Combined

FIGURE 46 shows an interpretation of what the proposed signing installation options might look like in the field.

FIGURE 46 Simulation of Proposed Single-Signing Recommendation.

Impact of Icon-Style Stop Bar Signs – An Estimate of Driver Understanding
An informal survey was given to 47 male civil engineering and construction management freshman-through-senior-level undergraduates on January 21st, 2009 to determine if they were aware of exactly where to place their vehicles when cued by a painted stop bar on the pavement at a stop-controlled intersection. Participants were told the purpose of the survey and given a two-page document with the information shown in FIGURES 47 and 48.

Imagine that you are the driver of this car, stopped at a three-legged intersection with stop signs on your approach indicating that you must make a complete stop before entering the main roadway upon which traffic does not stop.

FIGURE 47 Page 1 of Student Survey Document

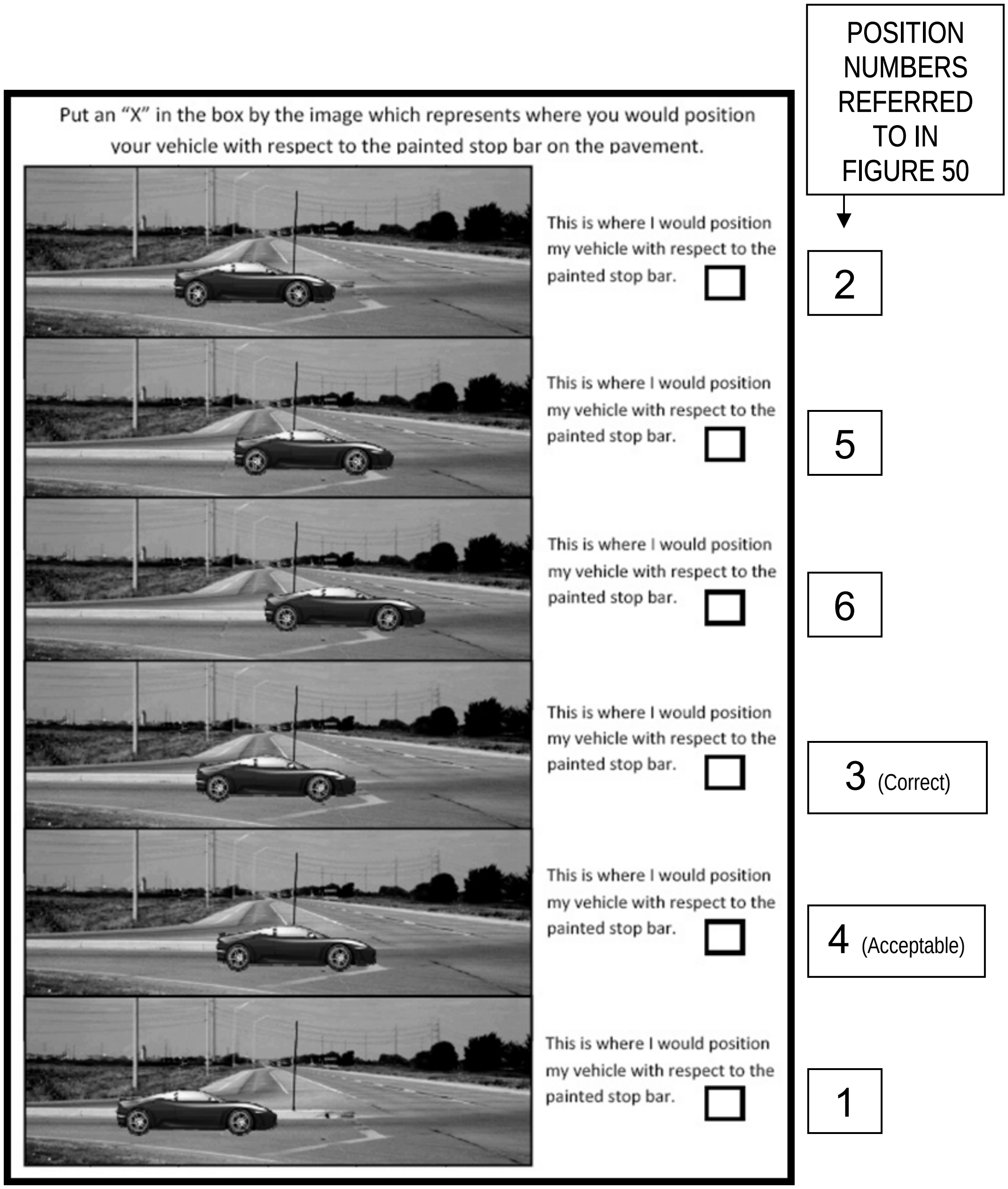


FIGURE 48 Page 2 of Student Survey Document

Students were asked to put an “X” in the box of the picture depicting where they would position their vehicles with respect to the painted stop line. FIGURE 48 shows 6 different positions of the vehicle with respect to the stop line, varying from several feet behind the stop bar (the last option, #6) to several feet beyond the stop bar the third option, #3). Positions were tabulated by using Position 1 to identify the farthest location of the vehicle BEHIND the stop bar to Position 6, the farthest location BEYOND the stop bar. These position numbers are shown to the right of FIGURE 48 for clarity purposes in further discussion. Location 3 is the desirable position for the vehicle and Location 4 is the closest option to the desirable one, considered to be acceptable.

In the following class period on January 26th, the students were told that the original surveys had been misplaced and that their responses were required again. The front page of the two-page survey was changed to show a closer view of the same intersection approach but this time with “STOP AT LINE” iconic signs under the stop signs, as shown in FIGURE 48. Page 2 of the second survey remained exactly the same as the first survey.

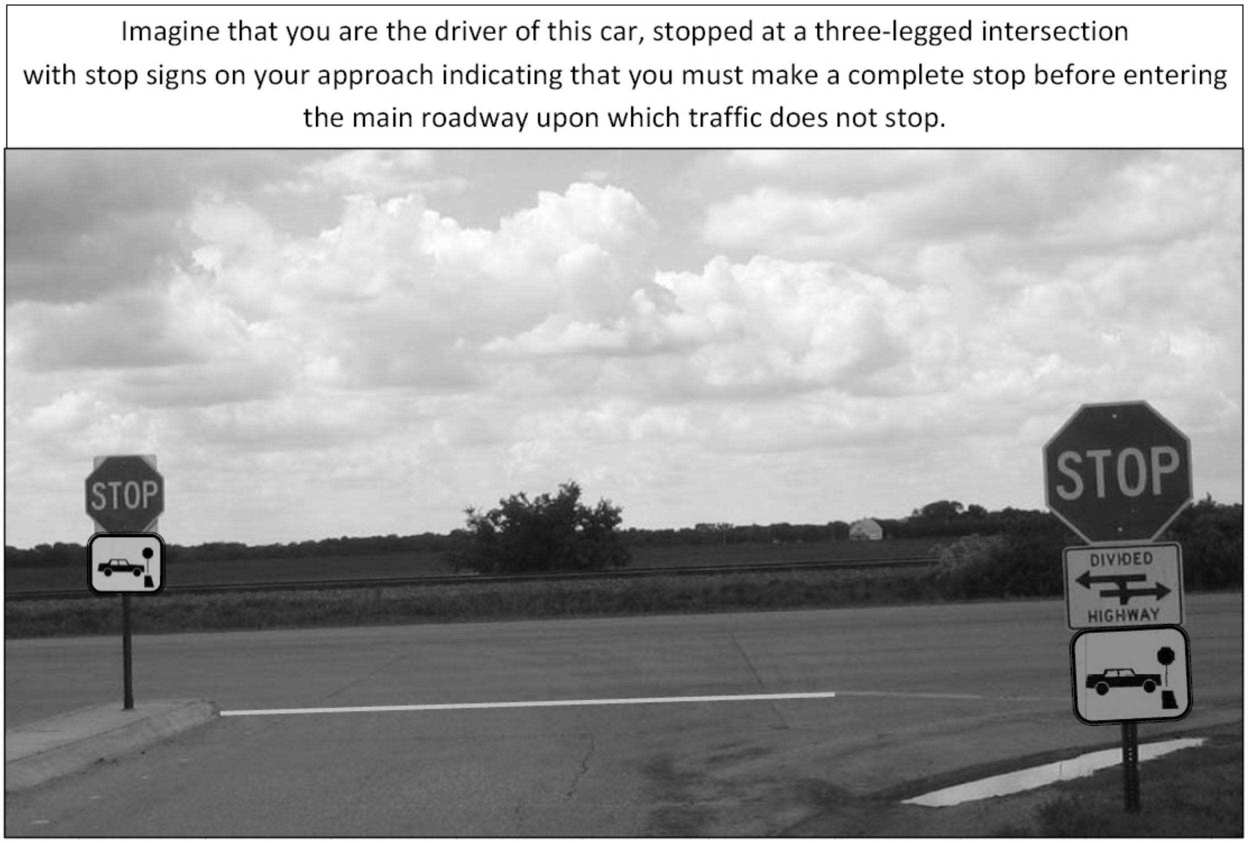
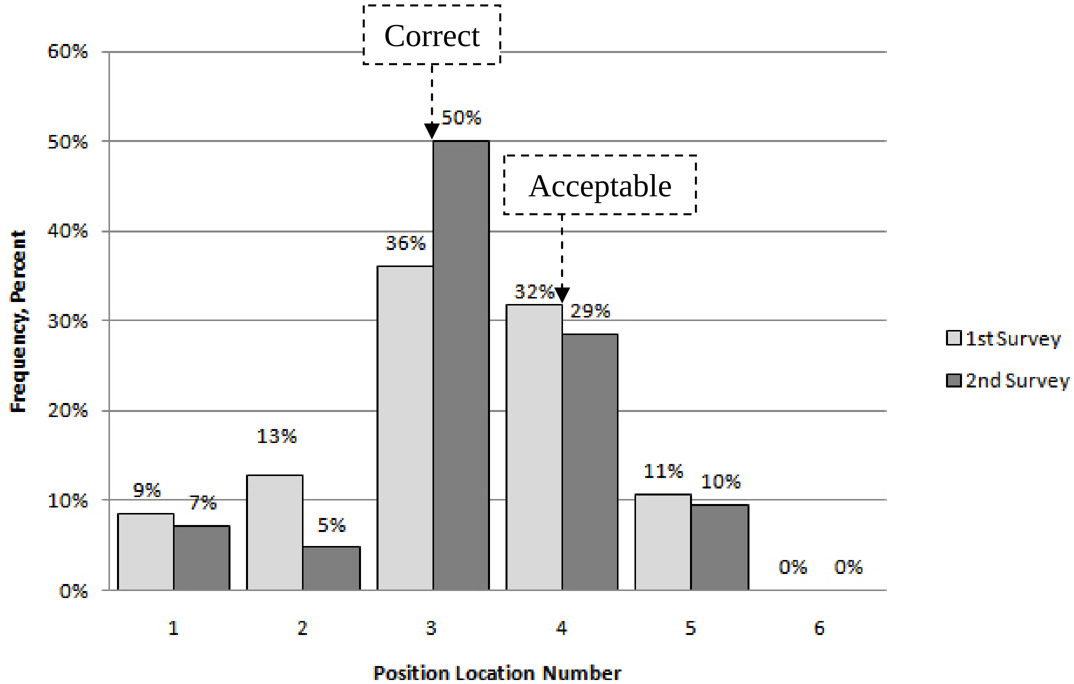


FIGURE 49 Page 1 of Second Survey



NOTE: Position 3 is correct, Position 4 is nearly correct

FIGURE 50 Stop Line Survey Results

Results of the two surveys are shown in FIGURE 50. About two-thirds of the participants knew the exact or approximate location of where to position their vehicles. This number increased to nearly four-fifths of participants when the iconic sign was included in the picture of the intersection approach. Although the survey was informal and does not accurately represent the varied cross section of the typical driver population, it does indicate that the majority of participants knew the appropriate behavior indicated by the stop bar and the iconic sign improved the success of their responses.

Chapter 10
SUMMARY OF PROJECT RECOMMENDATIONS

The following items are summarized for clarity in reiterating the recommendations derived from the findings described in this document.

Summary of Recommendations Based Upon Safety Study Aspect of the Project

- Results of the before-after comparison group safety studies concerning **crash frequency** indicated that signalization of MLA-type intersections results in improved safety, however no statistically significant difference was found at the 95 percent confidence level.
- Results of the before-after comparison group safety study of the conversion of one MLA-type intersection to an SLA configuration showed that the crash frequency was reduced when the approach was changed to a single lane. However, the study of **average crash rates** indicated that the MLA-type intersection had a statistically significant lower average than the SLA intersection at the 95 percent level of confidence. Also, the reduction of the number of approach lanes from two to one can increase driver delay and user costs.
- Comparison of 3-year **average crash rates** at MLA intersections with 2-lane major roads with similar statewide intersection averages indicates that they have a higher than average rate when the roadway design necessitates a horizontal curve along the major road or minor road horizontal alignment in the near proximity of the point of intersection.
- Comparison of 3-year average crash rates at MLA intersections with 4-lane major roads with similar statewide intersection averages indicates that they have a higher than average rate when in urban areas. Therefore, use of this type of intersection along 4-lane urban roadways should be limited.

If MLA-type intersections are determined to be the intersection type of choice:

- **Provide consistent and redundant positive visual guidance to promote the positioning of right-turning drivers in advance of left-turning drivers at MLA-type intersections.**
  Each visual cue issue, recommendation for improvement, explanation of recommendation and official guideline resource is summarized following FIGURES 38 and 39 in TABLE 24. FIGURE 40 shows a plan view of the proposed recommendations.
- **Develop a combined text and iconic STOP AT LINE sign.**
  Several designs should be tested with a pool of Nebraska drivers to determine the most easily interpreted design.
  Positioning of the sign should follow the guidelines in FIGURE 39 and TABLE 24.
- **Provide better driver information about the new proposed sign and the appropriate stop position at a stop bar location in the Nebraska Driver's Manual.**
  Additional information should be provided on page 40 of the current Nebraska Driver's Manual to better inform drivers about the desired stopping position at a painted stop bar on the pavement of a driving lane.

- **Update an MLA-type intersection using the proposals defined in the research report and conduct a before-after field study.**
  To better understand if the proposed recommendations result in a significant improvement in driver behavior, it is highly recommended that a field study be performed to quantify the improvement, if any.

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APPENDIX A
NATIONAL RESPONSE TO MLA ELECTRONIC SURVEY

To Whom It May Concern:

The Mid-America Transportation Center at the University of Nebraska-Lincoln is undertaking a research study on behalf of the Nebraska Department of Roads in the area of multiple approach lanes to stop-controlled intersections. As a portion of our preliminary research, we are surveying other state transportation departments for their policies on this matter, and we would appreciate your input. Does your particular state express written policy with respect to multiple lane approaches to stop signs and if so, could you fax a copy of your policy on the matter to xxx-xxx-xxxx?

FIGURE A.1: Message Distributed to State Transportation Agencies

TABLE A.1: State DOT Responses to Email Survey

State	No Written Policy	Follows MUTCD	Dislikes	Discourages Use
Arkansas	X			
Connecticut	X			
Idaho	X			X
Kentucky	X			
Maine	X		x	
Nebraska	X			
Ohio	X			
Pennsylvania		x		
Tennessee	X			
Wyoming	X		x	
Percentages	90%	10%	20%	10%

APPENDIX B
SUMMARY OF MLA DATABASE CHARACTERISTICS

The next two pages are a spreadsheet summary of the MLA data pool.

TABLE B.1: MLA stop-controlled intersections

Intersection Name	Intersection Skew Angle (degrees)	Major Road	Major Road Functional Class	Minor Road (stop control)	Minor Road Functional Class
US-6 & US-77	0	US-6	Principal Arterial	US-77	Principal Arterial
US-6 & N-15	0	US-6	Minor Arterial	N-15	Minor Arterial
W US-6 & US-281	0	US-6/34	Principal Arterial	US-281	Minor Arterial
US-6 & US-283	0	US-6/34	Principal Arterial	US-283	Minor Arterial
US-6 & S-1C	0	US-6/34	Principal Arterial	S-1C	Major Collector
US-6/34 & N-10	5	US-6/34	Principal Arterial	N-10	Minor Arterial
US-20 & N-110	3	US-20	Principal Arterial	N-110	
US-20 & N-29	0	US-20	Principal Arterial	N-29	Major Collector
US-26 & N-61	0	US-26	Principal Arterial	N-61	Minor Arterial
US-30 & N-19	24	US-30	Minor Arterial	N-19	Minor Arterial
US-30 & L-56G(to I-80)	5	US-30	Principal Arterial	L-56G	Major Collector
US-34 & N-1	0	US-34	Principal Arterial	N-1	Major Collector
E US-34 & N-2	13	US-34	Minor Arterial	N-2	Minor Arterial
US-75 & US-73	20	US-75	Principal Arterial	US-73	Principal Arterial
US-75 & N-4	0	US-75	Principal Arterial	N-4	Minor Arterial
US-75 & N-62	0	US-75	Principal Arterial	N-62	Major Collector
US-81 & L-85F	10	US-81	Principal Arterial	L-85F	Principal Arterial
US-81 & S-85H	0	US-81	Principal Arterial	S-85H	Principal Arterial
N US-81 & N-41	0	US-81	Principal Arterial	N-41	Major Collector
US-81 & N-121	15	US-81	Principal Arterial	N-121	Major Collector
S US-81 & N-41	0	US-81	Principal Arterial	N-41	Major Collector
US-81 & N-12	0	US-81	Principal Arterial	N-12	Minor Arterial
S US-34 & US-81	0	US-81	Principal Arterial	US-34	Minor Arterial
US-81 & US-136	0	US-81	Principal Arterial	US-136	Principal Arterial
US-183 & N-4	0	US-183	Principal Arterial	N-4	Minor Arterial
US-275 & US-275B	0	US-275	Principal Arterial	US-275B	Principal Arterial
US-275 & N-24	0	US-275	Principal Arterial	N-24	Major Collector
N US-281 & N-92	10	US-281	Principal Arterial	N-92	Minor Arterial
S US-385 & US-20	0	US-385	Principal Arterial	US-20	Principal Arterial
US-26 & L-62A	0	L-62A	Principal Arterial	US-26	Principal Arterial
N-2 & N-68	15	N-2	Principal Arterial	N-68	Major Collector
N-2 & 17th ST	5	N-2	Principal Arterial	17th ST	
N-2 & US-385	2	N-2		US-385	
N-4 & N-103	20	N-4	Minor Arterial	N-103	Minor Arterial
N-13 & N-121	0	N-13	Minor Arterial	N-121	Major Collector
E N-14 & N-91	15	N-14	Minor Arterial	N-91	Minor Arterial
W N-50 & N-4	5	N-50	Minor Arterial	N-4	Minor Arterial
S US-34 & N-61	0	N-61	Minor Arterial	US-34	Principal Arterial
S N-61 & N-92	0	N-61	Minor Arterial	N-92	Minor Arterial
E N-92 & N-15	0	N-92	Principal Arterial	N-15	Minor Arterial
N-92 & N-39	0	N-92	Minor Arterial	N-39	Minor Arterial
W N-92 & N-79	5	N-92	Principal Arterial	N-79	Major Collector
W N-92 & US-26	0	N-92	Minor Arterial	US-26	Principal Arterial
S N-92 & US-385	5	N-92	Major Collector	US-385	Principal Arterial
N-99 & N-4	0	N-99	Major Collector	N-4	Minor Arterial
S N-99 & N-8	0	N-99	Minor Arterial	N-8	Minor Arterial
US-34/75 & Rock Bluff Rd	0	US-34/75	Principal Arterial	Rock Bluff Rd.	

TABLE B.1
Continued

Intersection Name	City of Proximity	Legs*	Major Rd ADT (2003)	Minor Rd ADT (If Available)	Posted Major Speed	Posted Minor Speed
US-6 & US-77	Lincoln	3	7596		45	
US-6 & N-15	Seward	4*	1632		60	60
W US-6 & US-281	Hastings	4	4015	3295	60	60
US-6 & US-283	Arapaho	4	1940	3530	65	60
US-6 & S-1C	Hastings	4	6070	1240	60	
US-6/34 & N-10	Minden	4	1600	4640	35	55
US-20 & N-110	Jackson	4	3414	1760	60	
US-20 & N-29	Harrison	4	730	785	40	
US-26 & N-61	Ogallala	4	1555	2080	65	60
US-30 & N-19	Potter	3	2995	880	60	
US-30 & L-56G(to I-80)	North Pl	4	2545	3815	60	55
US-34 & N-1	Eagle	4	3090	1525	60	55
E US-34 & N-2	Grand Is	4*	7835	2290	60	60
US-75 & US-73	Dawson	4	2665	1100	60	60
US-75 & N-4	Dawson	4	2543	1500	60	60
US-75 & N-62	Dawson	4	2525	680	60	60
US-81 & L-85F	Hebron	4	1437	280	60	
US-81 & S-85H	Hebron	4	1797	515	55	55
N US-81 & N-41	Geneva	4	2300		35	55
US-81 & N-121	Yankton	4	6650	1295	60	55
S US-81 & N-41	Milligan	4	2300	675	60	60
US-81 & N-12	Crofton	4	4890	1740	60	60
S US-34 & US-81	York	4	5540	4258		
US-81 & US-136	Hebron	4	1500	1255	65	55
US-183 & N-4	Alma	4	2700	650	65	60
US-275 & US-275B	Norfolk	3			50	
US-275 & N-24	Norfolk	4	2716	3800	60	60
N US-281 & N-92	St. Paul	3	1974	2135	40	60
S US-385 & US-20	Chadron	4	3200	7099	45	
US-26 & L-62A	Bayard	3	1960	1850	65	
N-2 & N-68	Sweetwa	4	1985	2930	45	55
N-2 & 17th ST	Lincoln	3	18667		45	25
N-2 & US-385	Hemingf	4	1110	3200		
N-4 & N-103	Plymout	3	2035	1340	60	60
N-13 & N-121	Pierce	3	1565	1215	60	60
E N-14 & N-91	Albion	4*	4530	5400	30	55
W N-50 & N-4	Table Ro	3	1110	2030	60	60
S US-34 & N-61	Benklem	3	749	1110	60	
S N-61 & N-92	Lemoyne	3	675	1160	60	
E N-92 & N-15	Rising C	4	2650	1945	60	60
N-92 & N-39	Osceola	4	1780	770	60	
W N-92 & N-79	Rising C	4	2636	2425	60	
W N-92 & US-26	McGrew	3	2465	2327	60	
S N-92 & US-385	McGrew	3	406	2215	65	65
N-99 & N-4	Burchard	4	530	520	60	60
S N-99 & N-8	Summer	4	305	345	60	60
US-34/75 & Rock Bluff Rd	Union	4	6000			

APPENDIX C
MLA DATASET FOR EMPIRICAL BAYES ANALYSIS

The following pages are the complete data set for the MLA stop-controlled intersections used in the Empirical Bayes analysis for Hypotheses 1 and 2. The data is divided into 7 and 8 year increments for the purpose of publication.

	1989	1990	1991	1992	1993	1994	1995
N-2 & 17th ST							
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	2	1	1	0
PDO/N-R	1	0	0	0	0	1	4
Total	**1**	**0**	**0**	**2**	**1**	**2**	**4**
Rear End	0	0	0	0	0	0	2
Sideswipe	0	0	0	2	0	1	2
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	1	0	0
Turning	1	0	0	0	0	1	0
Other	0	0	0	0	0	0	0
	1989	1990	1991	1992	1993	1994	1995
S N-92 & US-385							
Fatal	0	0	0	0	0	0	0
Injury	0	0	1	0	0	0	1
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**0**	**1**	**0**	**0**	**0**	**1**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	1	0	0	0	1
	1989	1990	1991	1992	1993	1994	1995
W N-92 & US-26							
Fatal	0	0	0	0	0	0	0
Injury	2	0	0	0	0	0	0
PDO/N-R	1	2	1	0	1	0	0
Total	**3**	**2**	**1**	**0**	**1**	**0**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	1	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	2	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	1	2	0	0	1	0	0
	1989	1990	1991	1992	1993	1994	1995
US-26 & L-62A							
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0

	1989	1990	1991	1992	1993	1994	1995
N US-281 & N-92							
Fatal	0	0	0	0	0	0	0
Injury	2	0	0	0	1	0	0
PDO/N-R	1	2	1	1	1	0	2
Total	**3**	**2**	**1**	**1**	**2**	**0**	**2**
Rear End	0	2	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	1
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	1
Turning	2	0	0	0	2	0	0
Other	1	0	1	1	0	0	0
	1989	1990	1991	1992	1993	1994	1995
N-4 & N-103							
Fatal	0	0	0	0	0	0	0
Injury	1	0	0	1	0	0	0
PDO/N-R	0	2	0	0	0	0	0
Total	**1**	**2**	**0**	**1**	**0**	**0**	**0**
Rear End	0	1	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	1	0	0	0	0	0	0
Turning	0	0	0	1	0	0	0
Other	0	1	0	0	0	0	0
	1989	1990	1991	1992	1993	1994	1995
S US-34 & N-61							
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	1
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	1
	1989	1990	1991	1992	1993	1994	1995
S N-61 & N-92							
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	0	0	0	1	0	0	0
Total	**0**	**0**	**0**	**1**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	1	0	0	0

US-30 & N-19	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	1	0	0
Total	**0**	**0**	**0**	**0**	**1**	**0**	**0**
Rear End	0	0	0	0	1	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
W N-50 & N-4	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	1	0	0	0	1	0
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**1**	**0**	**0**	**0**	**1**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	1	0
Turning	0	0	0	0	0	0	0
Other	0	1	0	0	0	0	0
N-13 & N-121	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	1	0	1	0	0	1	0
Total	**1**	**0**	**1**	**0**	**0**	**1**	**0**
Rear End	1	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	1	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	1	0	0	0	0
	1989	1990	1991	1992	1993	1994	1995
W N-92 & N-79							
Fatal	0	0	0	0	0	0	0
Injury	0	1	0	0	0	0	1
PDO/N-R	0	2	0	0	0	0	0
Total	**0**	**3**	**0**	**0**	**0**	**0**	**1**
Rear End	0	0	0	0	0	0	1
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	1	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	2	0	0	0	0	0

	1989	1990	1991	1992	1993	1994	1995
US-6 & US-283							
Fatal	0	0	0	0	0	0	0
Injury	1	0	0	0	1	2	0
PDO/N-R	1	1	3	5	2	0	5
Total	**2**	**1**	**3**	**5**	**3**	**2**	**5**
Rear End	0	0	0	0	1	0	0
Sideswipe	0	1	0	2	0	0	1
Head-On	0	0	0	0	0	0	0
Angle	0	0	1	1	1	2	2
Turning	1	0	0	0	0	0	1
Other	1	0	2	2	1	0	1
	1989	1990	1991	1992	1993	1994	1995
US-6 & S-1C							
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	1	0	0	1
PDO/N-R	0	0	1	0	0	1	1
Total	**0**	**0**	**1**	**1**	**0**	**1**	**2**
Rear End	0	0	0	0	0	1	0
Sideswipe	0	0	1	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	1
Turning	0	0	0	0	0	0	0
Other	0	0	0	1	0	0	1
	1989	1990	1991	1992	1993	1994	1995
W US-6 & US-281							
Fatal	0	0	0	0	0	0	0
Injury	1	1	4	3	1	1	1
PDO/N-R	3	5	2	2	3	1	0
Total	**4**	**6**	**6**	**5**	**4**	**2**	**1**
Rear End	1	0	1	0	1	0	1
Sideswipe	1	2	0	0	0	1	0
Head-On	0	0	0	0	0	0	0
Angle	2	2	4	3	1	0	0
Turning	0	1	0	1	0	1	0
Other	0	1	1	1	2	0	0
US-75 & N-62	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	1	0	0	0	0	0	0
PDO/N-R	1	0	0	0	0	0	0
Total	**2**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	1	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	1	0	0	0	0	0	0

US-20 & N-110	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	1	0	0	1	0	0
PDO/N-R	0	1	0	0	0	0	1
Total	**0**	**2**	**0**	**0**	**1**	**0**	**1**
Rear End	0	1	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	1	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	1	0	1
N-2 & N-68	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	1	0	0	1	0	0	1
PDO/N-R	0	0	0	2	0	0	1
Total	**1**	**0**	**0**	**3**	**0**	**0**	**2**
Rear End	0	0	0	0	0	0	1
Sideswipe	0	0	0	1	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	1	0	0	1	0	0	1
Turning	0	0	0	0	0	0	0
Other	0	0	0	1	0	0	0
E US-34 & N-2	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	1	0	0	0
Injury	0	2	1	0	0	1	0
PDO/N-R	2	2	0	0	0	1	1
Total	**2**	**4**	**1**	**1**	**0**	**2**	**1**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	1	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	1	2	0	0	0	0	0
Turning	0	0	1	0	0	0	0
Other	1	1	0	1	0	2	1
N-92 & N-39	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	1	0	0	0	0	1	1
Total	**1**	**0**	**0**	**0**	**0**	**1**	**1**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	1	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	1	0	0	0	0	0	1

US-81 & N-12	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	1	1	0	1	1	0	3
PDO/N-R	0	0	1	0	1	1	2
Total	**1**	**1**	**1**	**1**	**2**	**1**	**5**
Rear End	0	0	0	0	1	0	1
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	1	0	0	1	1	3
Turning	0	0	0	0	0	0	1
Other	1	0	1	1	0	0	0
S N-99 & N-8	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
S US-385 & N-2	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	1	0	0	0
Injury	0	0	1	0	1	0	1
PDO/N-R	3	0	3	2	0	1	0
Total	**3**	**0**	**4**	**3**	**1**	**1**	**1**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	2	1	0	0	1
Turning	0	0	0	0	0	0	0
Other	3	0	2	2	1	1	0
S US-81 & N-41	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	1	1	1	0
PDO/N-R	0	0	1	1	0	0	0
Total	**0**	**0**	**1**	**2**	**1**	**1**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	1	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	1	1	1	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	1	0	0	0

US-81 & N-12	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	1	1	0	1	1	0	3
PDO/N-R	0	0	1	0	1	1	2
Total	**1**	**1**	**1**	**1**	**2**	**1**	**5**
Rear End	0	0	0	0	1	0	1
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	1	0	0	1	1	3
Turning	0	0	0	0	0	0	1
Other	1	0	1	1	0	0	0
S N-99 & N-8	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
S US-385 & N-2	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	1	0	0	0
Injury	0	0	1	0	1	0	1
PDO/N-R	3	0	3	2	0	1	0
Total	**3**	**0**	**4**	**3**	**1**	**1**	**1**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	2	1	0	0	1
Turning	0	0	0	0	0	0	0
Other	3	0	2	2	1	1	0
S US-81 & N-41	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	1	1	1	0
PDO/N-R	0	0	1	1	0	0	0
Total	**0**	**0**	**1**	**2**	**1**	**1**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	1	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	1	1	1	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	1	0	0	0

N US-81 & N-41	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	2	0	0	1	0	0	2
PDO/N-R	1	3	2	4	3	1	4
Total	**3**	**3**	**2**	**5**	**3**	**1**	**6**
Rear End	1	0	0	0	1	0	2
Sideswipe	0	0	1	2	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	2	0	2	2	1	2
Turning	2	0	1	0	0	0	1
Other	0	1	0	1	0	0	1
US-75 & US-73	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	0	1	0	0	0	0	1
Total	**0**	**1**	**0**	**0**	**0**	**0**	**1**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	1
Head-On	0	0	0	0	0	0	0
Angle	0	1	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
US-75 & N-4	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	1	0	0	1	0	1	0
PDO/N-R	0	1	0	0	0	0	0
Total	**1**	**1**	**0**	**1**	**0**	**1**	**0**
Rear End	0	0	0	0	0	1	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	1	0	1	0	0	0
Turning	0	0	0	0	0	0	0
Other	1	0	0	0	0	0	0
US-81 & N-121	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	1	0	1	1	0	0	0
PDO/N-R	0	0	0	2	1	1	1
Total	**1**	**0**	**1**	**3**	**1**	**1**	**1**
Rear End	0	0	0	1	0	0	0
Sideswipe	0	0	0	0	0	0	1
Head-On	0	0	0	1	0	0	0
Angle	1	0	0	0	1	0	0
Turning	0	0	1	0	0	0	0
Other	0	0	0	1	0	1	0

US-26 & N-61	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
US-6 & N-15	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	1	0	0	0	0	0
PDO/N-R	1	0	0	0	1	0	0
Total	**1**	**1**	**0**	**0**	**1**	**0**	**0**
Rear End	0	1	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	1	0	0	0	0	0	0
Other	0	0	0	0	1	0	0
US-183 & N-4	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	1	0	0
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**1**	**0**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	1	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
US-20 & US-385	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	1	0	0	0	2	0
PDO/N-R	0	2	0	3	0	1	1
Total	**0**	**3**	**0**	**3**	**0**	**3**	**1**
Rear End	0	0	0	0	0	1	0
Sideswipe	0	1	0	1	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	1	0	0	0	1	0
Turning	0	1	0	1	0	1	0
Other	0	0	0	1	0	0	1

US-30 & L56G	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	1	1
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**1**	**1**
Rear End	0	0	0	0	0	0	1
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	1	0
US-34 & Rock Bluff Rd	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	1	0	1	0	1	1	1
PDO/N-R	1	0	0	0	0	1	2
Total	**2**	**0**	**1**	**0**	**1**	**2**	**3**
Rear End	1	0	0	0	1	1	1
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	1	0	0	0	0
Turning	1	0	0	0	0	0	1
Other	0	0	0	0	0	1	1
US-275 & N-24	1989	1990	1991	1992	1993	1994	1995
Fatal	NA	NA	NA	NA	NA	NA	NA
Injury	NA	NA	NA	NA	NA	NA	NA
PDO/N-R	NA	NA	NA	NA	NA	NA	NA
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	NA	NA	NA	NA	NA	NA	NA
Sideswipe	NA	NA	NA	NA	NA	NA	NA
Head-On	NA	NA	NA	NA	NA	NA	NA
Angle	NA	NA	NA	NA	NA	NA	NA
Turning	NA	NA	NA	NA	NA	NA	NA
Other	NA	NA	NA	NA	NA	NA	NA
US-81 & S-85H	1989	1990	1991	1992	1993	1994	1995
Fatal	NA	NA	NA	NA	NA	NA	NA
Injury	NA	NA	NA	NA	NA	NA	NA
PDO/N-R	NA	NA	NA	NA	NA	NA	NA
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	NA	NA	NA	NA	NA	NA	NA
Sideswipe	NA	NA	NA	NA	NA	NA	NA
Head-On	NA	NA	NA	NA	NA	NA	NA
Angle	NA	NA	NA	NA	NA	NA	NA
Turning	NA	NA	NA	NA	NA	NA	NA
Other	NA	NA	NA	NA	NA	NA	NA

US-81 & L-85F	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
US-20 & N-29	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	1	0	0	0	1	0
PDO/N-R	1	2	0	0	0	0	0
Total	**1**	**3**	**0**	**0**	**0**	**1**	**0**
Rear End	0	0	0	0	0	1	0
Sideswipe	0	1	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	1	0	0	0	0	0	0
Turning	0	1	0	0	0	0	0
Other	0	1	0	0	0	0	0
US-34 & N-1	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	1	0	0	0	0
Injury	0	0	0	0	1	4	0
PDO/N-R	0	0	0	0	1	0	0
Total	**0**	**0**	**1**	**0**	**2**	**4**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	1	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	2	3	0
Turning	0	0	1	0	0	0	0
Other	0	0	0	0	0	0	0

N-14 & N-91	1989	1990	1991	1992	1993	1994	1995
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	1	0	0	0
PDO/N-R	0	0	0	2	1	1	0
Total	**0**	**0**	**0**	**3**	**1**	**1**	**0**
Rear End	0	0	0	1	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	1	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	1	1	1	0
	1989	1990	1991	1992	1993	1994	1995
E N-92 & N-15							
Fatal	0	0	1	0	0	0	0
Injury	0	1	0	0	2	2	0
PDO/N-R	1	2	0	0	1	1	0
Total	**1**	**3**	**1**	**0**	**3**	**3**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	1	1	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	1	0	0	2	1	0
Turning	0	0	0	0	0	1	0
Other	0	1	1	0	1	1	0
	1989	1990	1991	1992	1993	1994	1995
N-99 & N-4							
Fatal	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0

	1996	1997	1998	1999	2000	2001	2002	2003	2004
N-2 & 17th ST									
Fatal	0	0	0	0	0	0	0	0	0
Injury	1	0	2	1	0	0	1	0	1
PDO/N-R	1	0	2	2	0	2	1	1	4
Total	**2**	**0**	**4**	**3**	**0**	**2**	**2**	**1**	**5**
Rear End	2	0	0	0	0	0	0	0	1
Sideswipe	0	0	2	1	0	0	0	0	1
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	1	1	0	2	1	0	3
Turning	0	0	1	0	0	0	0	0	0
Other	0	0	0	1	0	0	1	1	0
	1996	1997	1998	1999	2000	2001	2002	2003	2004
S N-92 & US-385									
Fatal	0	0	0	0	0	0	0	0	0
Injury	1	0	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0	0	1
Total	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	1	0	0	0	0	0	0	0	1
	1996	1997	1998	1999	2000	2001	2002	2003	2004
W N-92 & US-26									
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	3	1	0	1	0
PDO/N-R	0	0	1	1	0	1	0	0	0
Total	**0**	**0**	**1**	**1**	**3**	**2**	**0**	**1**	**0**
Rear End	0	0	0	1	1	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	1	0	1	0	0	1	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	1	2	0	0	0
	1996	1997	1998	1999	2000	2001	2002	2003	2004
US-26 & L-62A									
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0	1	0
PDO/N-R	0	0	2	0	0	0	0	0	0
Total	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**1**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	1	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	2	0	0	0	0	0	0

N US-281 & N-92									
Fatal	0	0	0	0	0	0	0	0	0
Injury	1	0	0	0	0	1	0	0	0
PDO/N-R	1	0	0	1	2	1	1	1	0
Total	**2**	**0**	**0**	**1**	**2**	**2**	**1**	**1**	**0**
Rear End	1	0	0	0	0	0	0	1	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	1	1	0	1	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	1	0	0	0	1	2	0	0	0
	1996	1997	1998	1999	2000	2001	2002	2003	2004
N-4 & N-103									
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	2	0	0	0	0	0
PDO/N-R	1	0	0	0	1	1	3	1	0
Total	**1**	**0**	**0**	**2**	**1**	**1**	**3**	**1**	**0**
Rear End	0	0	0	0	0	0	1	0	0
Sideswipe	1	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	1	0	0	1	1	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	1	1	1	1	0	0
	1996	1997	1998	1999	2000	2001	2002	2003	2004
S US-34 & N-61									
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	1	0	0	0
PDO/N-R	0	0	1	0	1	0	0	0	0
Total	**0**	**0**	**1**	**0**	**1**	**1**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	1	0	1	1	0	0	0
	1996	1997	1998	1999	2000	2001	2002	2003	2004
S N-61 & N-92									
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0	0	0
PDO/N-R	1	0	1	0	1	0	0	0	0
Total	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	1	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	1	0	1	0	0	1	0	0	0

US-30 & N-19	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0
W N-50 & N-4	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0	1	0
PDO/N-R	0	1	0	0	2	1	0	0	0
Total	**0**	**1**	**0**	**0**	**2**	**1**	**0**	**1**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	1	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	1	0	0	2	0	0	1	0
N-13 & N-121	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	1	0	0	2	0	1	0	1
PDO/N-R	0	0	0	0	0	0	0	0	0
Total	**0**	**1**	**0**	**0**	**2**	**0**	**1**	**0**	**1**
Rear End	0	1	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	1	0	0	0	0
Turning	0	0	0	0	1	0	0	0	0
Other	0	0	0	0	0	0	1	0	1
	1996	1997	1998	1999	2000	2001	2002	2003	2004
W N-92 & N-79									
Fatal	0	0	0	1	0	0	0	0	0
Injury	0	0	1	0	0	0	0	1	2
PDO/N-R	0	0	0	0	1	1	0	0	1
Total	**0**	**0**	**1**	**1**	**1**	**1**	**0**	**1**	**3**
Rear End	0	0	0	0	0	0	0	0	1
Sideswipe	0	0	1	1	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	1	0	0	1
Turning	0	0	0	0	0	0	0	0	1
Other	0	0	0	0	1	0	0	0	0

	1996	1997	1998	1999	2000	2001	2002	2003	2004
US-6 & US-283									
Fatal	0	0	0	0	1	0	0	0	0
Injury	1	0	0	0	0	2	0	1	0
PDO/N-R	1	2	1	3	4	6	5	4	3
Total	**2**	**2**	**1**	**3**	**5**	**8**	**5**	**5**	**3**
Rear End	1	0	1	1	0	1	0	0	0
Sideswipe	0	1	0	0	1	1	0	1	1
Head-On	0	0	0	0	0	0	0	0	0
Angle	1	1	0	2	3	6	5	3	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	1	0	0	1	2
	1996	1997	1998	1999	2000	2001	2002	2003	2004
US-6 & S-1C									
Fatal	0	0	0	1	0	0	0	0	0
Injury	0	1	1	0	0	0	1	1	0
PDO/N-R	1	2	3	0	1	1	0	1	2
Total	**1**	**3**	**4**	**1**	**1**	**1**	**1**	**2**	**2**
Rear End	0	0	0	0	0	0	0	1	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	1	1	1	1	0	1	0	1
Turning	0	0	1	0	0	0	0	1	0
Other	1	2	2	0	0	1	0	0	0
	1996	1997	1998	1999	2000	2001	2002	2003	2004
W US-6 & US-281									
Fatal	0	0	0	1	0	0	0	0	1
Injury	2	0	1	3	2	3	1	2	3
PDO/N-R	2	3	3	5	3	3	4	4	3
Total	**4**	**3**	**4**	**9**	**5**	**6**	**5**	**6**	**7**
Rear End	0	0	0	1	2	1	1	0	0
Sideswipe	1	1	1	0	0	2	0	2	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	3	0	2	8	3	2	3	2	6
Turning	0	0	1	0	0	0	1	1	1
Other	0	2	0	0	0	1	0	1	0
US-75 & N-62	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	1	0	0	0
PDO/N-R	0	2	0	0	0	0	0	1	0
Total	**0**	**2**	**0**	**0**	**0**	**1**	**0**	**1**	**0**
Rear End	0	1	0	0	0	1	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	1	0	0	0	0	0	1	0

US-20 & N-110	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	1	0	1	2	2	0	1	0	1
PDO/N-R	0	2	0	2	1	2	0	1	1
Total	**1**	**2**	**1**	**4**	**3**	**2**	**1**	**1**	**2**
Rear End	0	0	0	1	2	0	1	0	0
Sideswipe	0	0	0	0	0	0	0	0	1
Head-On	0	0	0	0	0	0	0	0	0
Angle	1	0	0	1	0	1	0	0	0
Turning	0	0	0	0	0	0	0	1	0
Other	0	2	1	2	1	1	0	0	1
N-2 & N-68	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	1	1	0	1	0	0	0
PDO/N-R	1	0	0	2	0	0	0	2	0
Total	**1**	**0**	**1**	**3**	**0**	**1**	**0**	**2**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	1	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	1	3	0	1	0	1	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	1	0
E US-34 & N-2	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	1	0	0	1	0	1	0	1	0
PDO/N-R	0	0	2	6	0	0	3	1	1
Total	**1**	**0**	**2**	**7**	**0**	**1**	**3**	**2**	**1**
Rear End	0	0	0	1	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	1	0	2	1	0	0	0	1	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	5	0	1	3	1	1
N-92 & N-39	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0	0	0
PDO/N-R	0	0	0	2	0	0	1	0	0
Total	**0**	**0**	**0**	**2**	**0**	**0**	**1**	**0**	**0**
Rear End	0	0	0	1	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	1	0	0	0	0	0
Turning	0	0	0	0	0	0	1	0	0
Other	0	0	0	0	0	0	0	0	0

US-81 & N-12	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	1	3	1	2	2	0	1	1	2
PDO/N-R	0	2	2	1	2	1	1	1	0
Total	**1**	**5**	**3**	**3**	**4**	**1**	**2**	**2**	**2**
Rear End	0	0	0	0	1	0	0	1	0
Sideswipe	1	0	1	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	4	2	1	3	1	1	0	2
Turning	0	0	0	0	0	0	1	0	0
Other	0	1	0	2	0	0	0	1	0
S N-99 & N-8	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0	0	0
PDO/N-R	1	0	0	0	0	0	0	0	0
Total	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	1	0	0	0	0	0	0	0	0
S US-385 & N-2	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	1	1	0	0	0
PDO/N-R	0	0	0	1	0	1	0	0	1
Total	**0**	**0**	**0**	**1**	**1**	**2**	**0**	**0**	**1**
Rear End	0	0	0	0	1	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	1	0	1	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	1	0	0	1
S US-81 & N-41	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	1	0	0	0	0	0	N/A	N/A	N/A
Injury	0	0	0	0	0	1	N/A	N/A	N/A
PDO/N-R	1	0	0	0	0	0	N/A	N/A	N/A
Total	**2**	**0**	**0**	**0**	**0**	**1**	N/A	N/A	N/A
Rear End	0	0	0	0	0	0	N/A	N/A	N/A
Sideswipe	0	0	0	0	0	0	N/A	N/A	N/A
Head-On	0	0	0	0	0	0	N/A	N/A	N/A
Angle	1	0	0	0	0	1	N/A	N/A	N/A
Turning	0	0	0	0	0	0	N/A	N/A	N/A
Other	1	0	0	0	0	0	N/A	N/A	N/A

N US-81 & N-41	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	N/A	N/A	N/A
Injury	0	0	2	0	0	0	N/A	N/A	N/A
PDO/N-R	2	2	0	0	2	1	N/A	N/A	N/A
Total	**2**	**2**	**2**	**0**	**2**	**1**	N/A	N/A	N/A
Rear End	0	1	0	0	0	0	N/A	N/A	N/A
Sideswipe	0	0	0	0	0	0	N/A	N/A	N/A
Head-On	0	0	0	0	0	0	N/A	N/A	N/A
Angle	1	1	2	0	1	1	N/A	N/A	N/A
Turning	0	0	0	0	0	0	N/A	N/A	N/A
Other	1	0	0	0	1	0	N/A	N/A	N/A
US-75 & US-73	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	1	0	1	0
Total	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	1	0	1	0
US-75 & N-4	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0	0	0
PDO/N-R	0	0	0	1	1	0	0	1	0
Total	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**
Rear End	0	0	0	0	1	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	1	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	1	0
US-81 & N-121	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	1	1	0	0	0	1
PDO/N-R	1	1	0	0	0	0	0	0	0
Total	**1**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**1**
Rear End	0	0	0	1	0	0	0	0	0
Sideswipe	0	1	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	1	0	0	0	1
Turning	0	0	0	0	0	0	0	0	0
Other	1	0	0	0	0	0	0	0	0

US-26 & N-61	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	1	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	1	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0
US-6 & N-15	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0	1	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	1	0
US-183 & N-4	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	1	0	0	0	0
Injury	0	0	0	0	0	0	2	0	0
PDO/N-R	0	1	0	0	0	0	0	1	0
Total	**0**	**1**	**0**	**0**	**1**	**0**	**2**	**1**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	1	0	2	1	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	1	0	0	0	0	0	0	0
US-20 & US-385	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	2	0	3	0	0	1	0	3	0
PDO/N-R	1	1	2	4	4	3	3	1	1
Total	**3**	**1**	**5**	**4**	**4**	**4**	**3**	**4**	**1**
Rear End	1	0	2	2	2	1	0	0	0
Sideswipe	0	0	0	0	0	0	0	1	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	3	1	2	2	3	2	1
Turning	2	1	0	0	0	0	0	1	0
Other	0	0	0	1	0	1	0	0	0

US-30 & L56G	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	1	0
Injury	1	1	0	0	0	2	3	1	4
PDO/N-R	1	2	0	1	2	1	0	1	1
Total	**2**	**3**	**0**	**1**	**2**	**3**	**3**	**3**	**5**
Rear End	0	2	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	1	0	2	3	2	4
Turning	0	0	0	0	0	0	0	1	1
Other	2	1	0	0	2	1	0	0	0

US-34 & Rock Bluff Rd	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	1	0	0	0	0	0
Injury	0	0	0	0	0	0	1	0	0
PDO/N-R	2	2	1	0	1	2	2	2	0
Total	**2**	**2**	**1**	**1**	**1**	**2**	**3**	**2**	**0**
Rear End	1	0	1	0	0	0	1	0	0
Sideswipe	0	0	0	1	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	1	0	0	1	1	0	0	0
Turning	1	0	0	0	0	0	0	1	0
Other	0	1	0	0	0	1	2	1	0

US-275 & N-24	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	NA	NA	0	0	0	0	0	0	0
Injury	NA	NA	4	2	7	3	1	2	3
PDO/N-R	NA	NA	2	3	2	2	1	3	1
Total	**0**	**0**	**6**	**5**	**9**	**5**	**2**	**5**	**4**
Rear End	NA	NA	1	1	1	0	0	0	0
Sideswipe	NA	NA	0	0	1	0	0	0	0
Head-On	NA	NA	0	0	0	0	0	0	0
Angle	NA	NA	3	3	7	5	2	3	2
Turning	NA	NA	2	1	0	0	0	1	1
Other	NA	NA	0	0	0	0	0	1	1

US-81 & S-85H	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	NA	NA	0	0	0	0	0	0	0
Injury	NA	NA	0	1	0	0	0	0	0
PDO/N-R	NA	NA	0	0	0	0	0	0	1
Total	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**
Rear End	NA	NA	0	0	0	0	0	0	0
Sideswipe	NA	NA	0	1	0	0	0	0	0
Head-On	NA	NA	0	0	0	0	0	0	0
Angle	NA	NA	0	0	0	0	0	0	0
Turning	NA	NA	0	0	0	0	0	0	0
Other	NA	NA	0	0	0	0	0	0	1

US-81 & L-85F	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	1	0	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	0	0	0	1
Total	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	0	1
Turning	0	0	0	0	0	0	0	0	0
Other	1	0	0	0	0	0	0	0	0
US-20 & N-29	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	1	0	0	0	0	0
PDO/N-R	0	0	1	0	1	0	0	0	0
Total	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	1	1	1	0	0	0	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0
US-34 & N-1	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	1	0	2	0	0	0	1
PDO/N-R	0	0	1	0	0	0	0	0	1
Total	**0**	**0**	**2**	**0**	**2**	**0**	**0**	**0**	**2**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	2	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	1	0	0	0	1
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	1	0	0	0	1

N-14 & N-91	1996	1997	1998	1999	2000	2001	2002	2003	2004
Fatal	0	1	0	0	0	0	0	0	0
Injury	1	1	0	0	0	0	0	1	0
PDO/N-R	0	0	0	1	0	0	0	1	0
Total	**1**	**2**	**0**	**1**	**0**	**0**	**0**	**2**	**0**
Rear End	1	0	0	0	0	0	0	1	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	1	0	0	0	1	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	2	0	0	0	0	0	0	0
	1996	1997	1998	1999	2000	2001	2002	2003	2004
E N-92 & N-15									
Fatal	0	0	0	0	0	0	1	0	0
Injury	1	0	0	2	1	0	0	1	0
PDO/N-R	1	1	1	1	1	1	0	1	0
Total	**2**	**1**	**1**	**3**	**2**	**1**	**1**	**2**	**0**
Rear End	0	0	0	0	1	0	0	1	0
Sideswipe	0	0	0	1	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	2	1	0	1	0	1	0	1	0
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	1	1	1	0	1	0	0
	1996	1997	1998	1999	2000	2001	2002	2003	2004
N-99 & N-4									
Fatal	0	0	0	0	0	0	0	0	0
Injury	0	0	0	0	0	0	0	0	0
PDO/N-R	0	0	0	0	0	1	0	1	2
Total	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**2**
Rear End	0	0	0	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0	0	0	0
Head-On	0	0	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0	0	1
Turning	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	1	0	1	1

APPENDIX D
BASE NDOR INTERSECTION POOL FOR CRASH RATE ANALYSIS

Shown below are the individual crash rates for intersections obtained to test Hypotheses 3 and 4, categorized by stop- or signal-control.

TABLE D.1: Stop-controlled intersections used in crash rate analysis

Intersection Number	Speed Limit	Median Type	Median Width	# Thru Lanes	Total Acc's	ADT	Acc's/MV	# Legs	Signal or Stop
100800	40	Raised	16	4	7	12270	0.521	4	Stop
2810600	55	Barrier	22	6	57	66310	0.785	4	Stop
3001800	65	Depressed - Open	40	4	3	2882	0.951	4	Stop
5500800	65	Depressed - Open	40	4	4	10807	0.338	4	Stop
6600100	65	Depressed - Open	40	4	0	10118	0	4	Stop
6601300	60	Depressed - Open	40	4	2	5127	0.356	4	Stop
7000100	60	Depressed - Open	40	4	0	3524	0	4	Stop
7100400	65	Depressed - Open	30	4	2	6519	0.280	4	Stop
7802200	65	Depressed - Open	40	4	1	6611	0.138	4	Stop
7900500	65	Depressed - Open	30	4	1	6249	0.146	4	Stop
8400600	60	Depressed - Open	40	4	0	5096	0	4	Stop
8500500	65	Depressed - Open	40	4	1	4588	0.199	4	Stop
8500900	65	Depressed - Open	40	4	0	4499	0	4	Stop
8501000	65	Depressed - Open	40	4	0	4343	0	4	Stop
201100	65	None	0	2	2	1981	0.922	4	Stop
900300	65	Painted	0	2	0	2707	0	4	Stop
1402400	60	None	0	2	0	771	0	4	Stop
1700300	50	None	0	2	5	1081	4.224	4	Stop
2100500	25	None	0	2	6	8393	0.653	4	Stop
2300900	30	None	0	2	6	9667	0.567	4	Stop
2601000	60	None	0	2	0	2235	0	4	Stop
2810200	60	None	0	2	7	7726	0.827	4	Stop
4000300	35	None	0	2	8	5559	1.314	4	Stop
4200800	65	None	0	2	0	1797	0	4	Stop
5601800	65	None	0	2	0	1852	0	4	Stop
6101200	60	Painted	0	2	0	1433	0	4	Stop
6701400	60	None	0	2	0	1689	0	4	Stop
6800100	60	None	0	2	2	4027	0.454	4	Stop
9100900	55	None	0	2	3	1138	2.407	4	Stop
1300900	55	None	0	2	0	2395	0	3	Stop
2100400	65	Painted	0	2	1	2397	0.381	3	Stop
2100800	65	None	0	2	0	2249	0	3	Stop
4801000	45	None	0	2	0	4521	0	3	Stop
5200400	60	None	0	2	0	353	0	3	Stop
5600600	65	None	0	2	0	1958	0	3	Stop
7600900	50	Painted	0	2	4	5535	0.660	3	Stop
9000100	60	None	0	2	1	3330	0.274	3	Stop
6300100	60	None	0	3	0	2805	0	3	Stop
2200400	55	None	0	3	2	4702	0.388	3	Stop
2600700	55	None	0	3	0	2531	0	3	Stop
1600700	35	None	0	4	2	9534	0.192	3	Stop
6600600	65	Depressed - Open	40	4	1	10215	0.089	3	Stop

TABLE D.2: Signal-controlled intersections used in crash rate analysis

Intersection Number	Speed Limit	Median Type	Median Width	# Thru Lanes	Total Acc's	ADT	Acc's/MV	# Legs	Signal or Stop
4800600	35	Raised	14	3	2	9051	0.202	4	Signal
6101100	60	Painted	0	2	4	4094	0.892	4	Signal
9000300	30	None	0	2	9	13290	0.618	4	Signal
9300600	60	None	0	2	2	3902	0.468	4	Signal
5501300	45	Raised	16	5	110	55985	1.794	4	Signal
5600400	55	Raised	16	2	6	9117	0.601	4	Signal
7300200	35	None	0	4	5	13715	0.333	4	Signal
7700700	35	Raised	16	4	12	14870	0.737	4	Signal
7706200	55	Raised	16	4	110	49549	2.027	4	Signal
7706300	45	Raised	16	4	109	70703	1.408	4	Signal
7901000	45	Raised	16	4	15	19333	0.709	4	Signal
7902000	55	Raised	16	4	18	10181	1.615	4	Signal
2401400	35	None	0	2	1	5013	0.182	4	Signal

APPENDIX E

Shown below are the remaining ANOVA tests conducted in SPSS for the crash rate analysis.

TABLE E.1: ANOVA 1

Source	TIII Sum of Squares	Df	MSE	F	p-value
Corrected Model	6.368	9	.708	1.905	.062
Intercept	8.580	1	8.580	23.096	.000
INT_TYPE (MLA Stop, SLA Stop, Signalized	1.031	2	.515	1.388	.255
THREELEG (Yes, No)	.570	1	.570	1.533	.219
TWOLANES (Yes, No)	.01433	1	.01433	.039	.845
INT_TYPE*THREELEG	.187	1	.187	.504	.480
INT_TYPE*TWOLANES	1.406	2	.703	1.893	.157
THREELEG*TWOLANES	.09982	1	.09982	.269	.606
INT_TYPE*THREELEG*TWOLANES	.230	1	.230	.619	.434
Error	31.577	85	.371		
Total	59.076	95			
Corrected Total	37.945	94			

TABLE E.2: ANOVA 2

Source	TIII Sum of Squares	Df	Mean Square	F	p-value
Corrected Model	19.166	13	1.474	6.359	.000
Intercept	11.673	1	11.673	50.350	.000
INT_TYPE (MLA Stop, SLA Stop, Signalized	2.493	2	1.246	5.376	.006
SPD_LMT (45,50,60)	1.206	2	.603	2.602	.080
THREELEG (Yes, No)	4.865	1	4.865	20.986	.000
INT_TYPE * SPD_LMT	6.926	4	1.732	7.468	.000
INT_TYPE * THREELEG	.228	1	.228	.982	.325
SPD_LMT * THREELEG	4.784	2	2.392	10.317	.000
INT_TYPE * SPD_LMT * THREELEG	.251	1	.251	1.085	.301
Error	18.779	81	.232		
Total	59.076	95			
Corrected Total	37.945	94			