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SAFETY OF INTERSECTIONS ON HIGH-SPEED ROAD SEGMENTS WITH SUPERELEVATION

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<p>16. Abstract</p> <p>In recent years, the State of Indiana has built a number of intersections where one or both of the roads are located on curves. The AASHTO <i>Policy on Geometric Design of Highways and Streets</i> recommends that in such cases “the alignment should be as straight and the gradient as flat as practical.” This wording, consistent with Part V of the Indiana Design Manual, allows for the design of intersections on curves if other solutions prove to be too expensive.</p> <p>Several of these intersections have raised safety concerns and led to expensive corrective measures. Due to these safety and economic issues, INDOT currently avoids designing intersections on segments with steep superelevation. The focus of this research is to determine what effect curvature and superelevation have on intersection safety. Based on the results, the goal is to provide design standards for curvature and superelevation for cases where the major road is located on a superelevated curve.</p>					
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IMPLEMENTATION REPORT

The research objectives of the completed project included: evaluation of safety at intersections located on horizontal curves on high-speed rural roads in Indiana, investigation of safety factors at these intersections, and identification of promising measures of safety improvements. These objectives have been accomplished through statistical analysis of crashes and geometry data. The research project has confirmed that intersections on horizontal curves of high-speed four-lane rural roads exhibit more severe crashes and at higher rates than similar intersections on tangent segments. The relationship between the road horizontal curvature and the increase in the crash frequency is provided. In addition, the results indicate that intersections on curves are more dangerous at night than during a day and that this safety deterioration is considerably larger at intersections on horizontal curves than on tangent segments.

The results of the research could be implemented by the INDOT safety management in two ways:

- (1) The developed crash prediction model can be used to identify hazardous intersections on curves, and
- (2) The road lighting should be considered at hazardous intersections located on horizontal curves.

The results could also be implemented in roadway design. The relationship between the horizontal curvature and the increase in the number of crashes provides a basis for determining the minimum radius of a horizontal curve if an intersection is present on the curve. The recommendation might be included in the revised INDOT design manual.

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CHAPTER 1. INTRODUCTION

Designers have to deal with road crossings where the major road is located on a superelevated curve. In such cases, the AASHTO Policy on Geometric Design of Highways and Streets (AASHTO, 2001) recommends that “the alignment should be as straight and the gradient as flat as practical.” This wording allows for designing intersections on curves if other solutions are prohibitively expensive. The Policy warns, however, that “This practice may have the disadvantage of adverse superelevation for turning vehicles and may need further study where curves have high superelevation rates and where the minor-road approach has adverse grades and a sight distance restriction due to grade line.” It goes further to say, “The combination of vertical and horizontal curvature should allow adequate sight distance at an intersection.” In the summary, the national policy does not forbid locating intersections on curves if other solutions deem to be expensive but it recommends avoiding this where practical.

Part V of the Indiana Design Manual (INDOT, 1994) is consistent with the national standards and does not strictly forbid the design of intersections on curves. Consequently, the Indiana Department of Transportation (INDOT) has built a number of such intersections. Some of these intersections have raised safety concerns, most notably the intersection of US-31 and SR-14 in Rochester. Following a series of recurring fatal events, INDOT made the decision to close turning movements at this intersection.

Due to situations like the one in Rochester, INDOT currently avoids designing intersections on segments with a steep superelevation. This design restriction calls for expensive alternatives, such as realigning roads or adding grade separations (bridges). In the Rochester case, a bridge to allow SR-14 trips to cross over the mainline is currently programmed for construction in the near future. In the design of a new multi-lane relocation of US-231 in Spencer County, a decision was made to disallow county road and state road intersections in areas of high superelevation on the mainline. In addition, a planned section of US-231 around Dale, Indiana with maximum curvature and high superelevation was relocated in order to provide a horizontal curve requiring a lesser rate. The purpose of this research is to address these design issues associated with locating intersection on curves.

Specifically, the objectives of this research are:

- To determine whether or not superelevated intersections are truly more dangerous than similar intersections located on tangents.
- If these intersections are more dangerous, to determine what geometric characteristic or combination of characteristics makes them more dangerous.
- To recommend cost-effective safety improvements at existing superelevated intersections.
- To propose design recommendations for cases where an intersection is being considered for design on a superelevated curve.

The project examines two-way stop-controlled intersections where the mainline is located on a superelevated curve. The focus was on high-speed divided highways, but two-lane roads were also examined in an attempt to gain further information on potential safety factors. This report attempts to determine and explain the underlying causes of the crashes and provide general countermeasures. The desired product is a set of design rules that address safety at new and existing superelevated intersections.

The remainder of this report is divided into six additional chapters. Chapter 2 presents a literature review of methodologies and results from past research done in the area of highway safety. Chapter 3 discusses the methodology followed in this research. Chapter 4 provides an analysis of curve effect using a sample of state-state intersections where both routes are two-lane roads. Chapter 5 provides a comprehensive analysis of intersections along four-lane divided highways, such as the aforementioned intersection of US-31 and SR-14. Chapter 6 presents details on the most frequent crash type, occurring between vehicles on the outside of the major road and vehicles attempting to cross from the median. Chapter 7 summarizes the research findings and provides design recommendations for cases where an intersection is being considered for design or improvement on a superelevated curve.

CHAPTER 2. LITERATURE REVIEW

In this chapter, past research related to intersection safety is reviewed. The focus is on determining whether certain intersection geometric characteristics, particularly superelevation, adversely affect safety in terms of both accident frequency and severity. Methodologies and results of past studies are discussed.

2.1. Methods of Safety Analysis

Recent research has pointed out a number of alternative methods of safety analysis. Among the methods considered for this research were safety audits, collision diagrams, direct traffic observation, and statistical analysis.

Road safety audits, or safety reviews, are an emerging method of investigating hazard problems with possible application to existing roads (Pietrucha et. al., 2000). Safety audits applied to existing roads typically involve a comprehensive field review of each location by a team of safety experts. However, the safety audits method is not useful in this case because safety audits refer to expert knowledge and judgment while the research problem to address in this research calls for an objective exploration of what is unknown.

The traditional safety analysis based on collision diagrams is concentrated on evaluating compliance of roadway design to the design standards (Missouri Highway and Transportation Department 1990). These safety reviews do not typically consider human factors, such as visibility issues. Additionally, this approach does not allow for generalization of the findings. For these reasons, the traditional approach is not an appropriate method for this study.

Direct observations of traffic operations may give clues about potential causes of crashes (G.D. Hamilton Associates Consulting, 1996). By observing driver behavior, insight can be gained in regard to human behavior to complement the geometric design characteristics. However, this approach is resource demanding and the linkage with crash occurrences cannot be ascertained.

The complexity, diversity, and stochastic nature of transportation problems make statistical modeling a promising choice (Washington et. al., 2003). Based upon the needs of this research, statistical analysis is the appropriate method of safety analysis.

2.1.1. Statistical Modeling

Statistical modeling techniques have been used to identify geometric characteristics that make an intersection more or less safe in terms of both accident frequency and severity. Several forms of statistical models can be used to isolate such characteristics. The first models to be discussed are the frequency, or count data, models. Count data models are appropriate for determining safety factors that affect the frequency of accidents at a given location. The second models discussed are discrete outcome models. Discrete outcome models are used to determine safety factors that increase the probability of an accident being of a particular severity given the fact that the accident has occurred. Count data and discrete outcome models are discussed at greater lengths in the following sections.

2.1.1.1. Count Data Models

Many types of accident frequency models have been developed over time. Early models used conventional linear regression. However, Miaou and Lum (1993) showed these types of models to be inappropriate for modeling accident frequencies. Due to the random nature of crashes, they concluded that Poisson and negative binomial regression models provided a more reasonable approximation of crash counts. In recent years, many researchers have developed models of these particular forms. Pickering et al. (1986), Vogt and Bared (1998), and Bauer and Harwood (1996) all utilized Poisson models in their research. Hauer et al. (1988), Bonneson and McCoy (1993), Poch and Mannering (1996), Vogt and Bared (1998), and Tarko et al. (2000) all used negative binomial models in their research.

Selection of an appropriate model between the Poisson and the negative binomial is based upon the presence of overdispersion in the data. Overdispersion results when the variance of the predicted variable is greater than the mean. This is often the case in transportation safety analysis. If overdispersion exists, the negative binomial distribution is appropriate. If there is no overdispersion, the negative binomial distribution collapses to a Poisson. For modeling purposes, the negative binomial is preferred to the Poisson because exclusion of the overdispersion parameter may lead to incorrectly specified parameters in the

model. The variability otherwise explained by overdispersion will instead be incorrectly incorporated into other variables.

In addition to overdispersion, another factor affecting the selection of an appropriate model is the number of zeroes in the sample. Shankar et al. (1997) explain a procedure for determining the appropriate model specification for crash data. They argue that the traditional Poisson and negative binomial models do not address the possibility of a zero-inflated counting process. They distinguished the truly safe road section (zero accident state) from the unsafe section (non-zero accident state) to show that a zero-inflated version of the model is more appropriate in many cases. Zero-inflated probability processes allow one to better isolate independent variables that determine the relative accident likelihoods of safe versus unsafe roads.

Miaou (1989) developed a test for determining whether the zero-inflated state was justified. It was recommended that Poisson models be used if the mean and variance of the accident frequencies is approximately the same. If overdispersion, the case where the variance is significantly greater than the mean, is present, the negative binomial and zero-inflated Poisson (ZIP) models were found to be more appropriate. It is important to note that there may be other reasons for excess zeroes, such as underreporting of accidents. Underreporting may be a particular problem for rural intersections. For this reason, there must be clear justification for selecting a zero-inflated model over the traditional negative binomial model.

2.1.1.2. Discrete Outcome Models

The severity of an accident is typically classified into one of several categories, such as property damage only (PDO), injury, or fatality. As such, accident severity can be classified as a discrete outcome. An appropriate method of modeling such data is the multinomial logit (MNL) formulation (Washington et al., 2003). More recent applications have used nested logit models in their evaluations. The nested logit accounts for shared characteristics among severity levels that would otherwise result in an incorrectly specified model.

2.2. Results of Past Research

This section presents a review of past research in the area of highway safety. These findings show relationships between crashes and traffic volume, geometric characteristics, and weather.

2.2.1. Traffic Volumes

The primary contributing factor relating highway variables to crashes has been shown to be traffic. Various predictive models have been developed over time relating crashes to traffic volume. Pickering, Hall, and Grimmer (1986) examined crashes at three-legged intersections on two-lane roads. Their Poisson model predicted the mean number of crashes per unit time and was of the form:

$$N=K*(ADT_1*ADT_2)^{0.5},$$

where:

N = number of crashes per unit time

K = constant

ADT₁ = Average Daily Traffic (ADT) on major road

ADT₂ = Average Daily Traffic (ADT) on minor road.

The preceding model found the product of the traffic volumes on each road to be most appropriate for modeling purposes. Bonneson and McCoy (1993) conducted a study of 125 non-urban four-legged intersections in Minnesota. They also found ADT values to be the only significant variables contributing to accident frequency. In their case, separate variables were created for the ADT on each road as shown here:

$$N = K*(ADT_1)^{0.256}(ADT_2)^{0.831},$$

where:

N = mean number of crashes per unit time

K = constant

ADT₁ = ADT on major road

ADT₂ = ADT on minor road

Hauer, Ng, and Lovell (1988), Hakkert and Mahalel (1978), and David and Norman (1975) also found traffic to be the only significant factor in past analyses. Traffic is the only factor included in the models presented here and is the major variable present in most other models, as well. However, it is also the one factor that is outside the direct control of transportation agencies. In order to make decisions related to safety, one must have something on which to base their decisions. Past research has shown a variety of geometric design elements to have a wide range of effects on the number of crashes at an intersection. These design elements are of particular concern because they may help transportation professionals to correct and avoid potential safety problems.

2.2.2. Geometric Characteristics

The design elements of primary concern in this research are horizontal alignment and superelevation. Horizontal curves have been shown to increase the crash rate by 1.5 to 4 times that of a similar tangent section (Zeeger et al., 1992). Further explanation of the relationship between curvature and safety are provided by McGee et al. (1995) and Vogt and Bared (1998). Shankar et al. (1995) note increasing curvature as having a negative impact on safety in their study of rural freeway accidents. High superelevation rates, as are common with horizontal curves, also lead to increases in accidents according to Zeeger et al. (1992). He concluded that improving the superelevation of curves below the AASTHO guidelines would yield an expected reduction of up to 11%. Hauer (1997) found that for any given deflection angle, the design with the larger curve radius is always safer than a similar intersection with a smaller radius value. Furthermore, he found the change in accidents to be proportional to the change in radius length.

The presence of vertical curves also appears to increase crash frequency according to Shankar et al. (1995) and Vogt and Bared (1998).

A model developed by David and Norman (1975) shows that the presence of auxiliary turning lanes is likely to decrease the number of accidents. Several other authors, including Bauer and Harwood (1996) have shown similar results, particularly for the presence of left-turn lanes.

Hanna et al. (1976) found an increase in crashes associated with limited sight distances at both signalized and unsignalized intersections. Bared and Lum (1992) also found that shorter sight distances result in higher crash rates.

McCoy, Tripi, and Bonneson (1994) determined crashes increase the further an intersection angle is from 90 degrees. Bared and Lum (1992) and Bauer and Harwood (1996) found right-angle intersections to be more dangerous than those that are only slightly skewed. This was verified by Vogt and Bared (1998) for rural intersections.

Bauer and Harwood (1996) found that wider lanes and shoulders result in fewer multiple-vehicle crashes. Harwood et al. (1995) found that wider medians also results in fewer crashes for rural unsignalized intersections.

Signalization is typically beneficial for intersections with higher volumes, but may increase the number of accidents for a low-volume intersection. King and Goldblatt (1975) found

that signalization does not reduce the overall number of crashes, but instead causes more rear-end and fewer right-angle crashes.

Hagiwara et. al. (1999) found that drivers had greater difficulty detecting curve characteristics at night, particularly in sections with no lighting. Bauer and Harwood (1996) found that the absence of lighting increased crash frequency in their study of rural intersections.

Vogt and Bared (1998) found roadside hazards increased accidents on three-legged intersections. They used the Roadside Hazard Rating developed by Zeeger et al. (1987).

Blower, Campbell, and Green (1993) found truck crashes to be more prevalent in rural environments and during the night. This may be picking up human factors, such as tiredness, as well as design, such as lighting.

2.2.3. Weather

Vogt and Bared (1998) found regional weather to be insignificant in crash prediction. However, Shankar, Mannering, and Barfield (1995) find extreme weather to be a factor in combination with extreme horizontal or vertical alignment. In their study of crashes in the province of Quebec, Brown and Baass (1997) found crash rates to be the highest during the winter months of December through March. They also found that during the winter season, crashes were least severe, a possible indication of greater caution being exercised on behalf of drivers due to the inclement weather conditions.

CHAPTER 3. METHODOLOGY

3.1. INTRODUCTION

The research methodology was developed from an extensive study of past research. This chapter explains the methodology in detail, focusing on the following topics:

- Intersection Selection
- Data Collection
- Statistical Analysis

3.2. INTERSECTION SELECTION

The first step in this study of intersection safety was to develop a method of selecting intersections for analysis. Two sets of intersections were required, one for intersections with two lanes on all approaches and another with four lanes on major approaches. The two-lane analysis focused only on the intersection of state routes. This criterion was used because it greatly reduced the need for data collection as a large amount of information was readily available directly from INDOT. Conversely, the four-lane analysis examined intersections with local and county roads, leading to more rigorous data collection. It was necessary to include these roads because the sample size of state-state intersections that fit this criterion was very small.

3.3. DATA COLLECTION

Data for the project was obtained in one of two ways. All crash data and traffic volumes were obtained from INDOT. The remaining data was collected directly in the field. Field collection included measuring geometric characteristics of the roadway and counting traffic for local and county roads. The amount of data collection required varied in each of the two analyses and is explained further in the respective chapters.

3.4. Statistical Analysis

Upon completion of data collection, a statistical analysis was conducted to determine those characteristics having an impact on intersection safety. The statistical analysis involved the development of econometric models to determine the effects of variables for which complete information was available, such as geometry. In the case of variables for which complete information was not available, such as weather, the effects were quantified by comparing the proportion of crashes between two samples, one sample of intersections on curves and one with intersections on tangents. Each of these approaches is discussed further in the following sections.

3.4.1. Econometric Modeling

The econometric modeling for this project focuses on two separate types of models, a frequency model to predict the number of accidents at a given intersection per some unit time and a severity model to predict the damage caused in a particular accident. These models are used to determine what geometric characteristics tend to make intersections more or less safe. An explanation of the appropriateness of these models is available in the preceding chapter (Section 2.1.1). To develop these models, a number of software packages were considered, including STS, SAS, and LIMDEP. The determination was made to use the modeling program LIMDEP 7.0. LIMDEP is a package for estimating and analyzing econometric models. It is primarily oriented toward cross section and panel data and, for this reason, was well-suited for this project.

The modeling of the data in this study was done using LIMDEP 7.0 software. LIMDEP provides maximum likelihood estimates and standard error values for each coefficient. Additionally, P-values are provided which test the null hypothesis that the true value of a regression coefficient is zero. The z-score of an estimated coefficient is the estimated coefficient value divided by the estimated standard error. The P-value is the probability that a normal random variable has an absolute value larger than the z-score obtained. If the P-value is small, there is good evidence that the corresponding variable is statistically significant. For the purpose of this research, a threshold P-value of 0.10 was used to determine statistical significance. All parameters with P-values below 0.10 were included in the final models. However, even if the P-value is above the threshold, the parameter estimate may have some practical significance. For instance, a variable may have a P-value of 0.25, but the estimated coefficient may indicate a significant impact and could become significant if the sample size were increased. As such, parameters demonstrating a high level of practical significance were included in the final models where appropriate.

Using LIMDEP and a stepwise modeling approach, models were developed for both the two-lane and four-lane cases. In each case, an initial “full” model was developed that included all variables. Initial problems, such as multicollinearity, were addressed and affected variables were removed as appropriate. The resulting “full” model most completely explains the effects of the variables on intersection safety. Though not all variables are statistically significant in the initial model, many displayed practical significance and would likely become statistically significant if the sample size were increased. In the next step, variables were removed from the initial model based upon p-values. After removing the variable in the model with the highest p-value, the coefficients and p-values of the remaining variables were examined for changes due to multicollinearity. Models were reduced until all variables had p-values of 0.10 or less to arrive at the final “reduced” model. As variables were removed, some coefficients of other variables changed. This is because the variation previously explained by the removed variable was now being explained by one or more of the remaining variables. The closer the coefficients are for a variable between the full and reduced models, the more accurate the estimate.

3.4.2. Crash Frequency Analysis

In accident analysis, the consensus of all contemporary empirical work is that Poisson and negative binomial regression count models are the most appropriate methodological techniques for frequency modeling. As an extension of standard Poisson and negative binomial regression, zero-inflated Poisson (ZIP) and zero-inflated negative binomial (ZINB) regression models have gained considerable recognition in accident frequency analysis. These models account for the fact that the traditional application of Poisson and negative binomial models does not address the possibility of zero-inflated counting processes. Zero-inflation may be present because some intersections have accident probabilities that are so low over some time period that they can be considered to be virtually safe. Such intersections are said to be in a zero-accident state. Other intersections may follow a normal count process for accident frequency in which non-negative integers, including zero, are possible outcomes over the same time period. Each of the aforementioned modeling forms is discussed at greater length throughout this section, beginning with the Poisson model.

For the Poisson model, the probability of an intersection, i , having y_i accidents over a period of time is given by the following equation:

$$P(Y_i = y_i) = P(y_i) = \frac{EXP(-\lambda_i) \lambda_i^{y_i}}{y_i!},$$

where:

$P(y_i)$ =the probability of intersection i having y accidents over the time period

λ_i =the expected value (Poisson parameter) of y_i .

The Poisson parameter is equal to the expected number of accidents at the intersection over period i and is denoted by $E(y_i)$. This parameter is specified as a function of explanatory variables. For crash analyses, these variables may include traffic volumes, roadway geometry, weather conditions, and other related factors. The log-linear model, shown below, is the most common relationship between the Poisson parameter and the explanatory variables.

$$E(y_i) = \lambda_i = EXP(\beta X_i),$$

where:

X_i =vector of explanatory variables

β =vector of estimable parameters.

A severe limitation of the Poisson distribution is that the variance and mean of the predicted variable must be equal. The possibility of overdispersion, or having a variance greater than the mean, may result in biased, inefficient coefficient estimates. To relax this overdispersion constraint, a negative binomial distribution is commonly used instead of a Poisson distribution. The negative binomial model is obtained by adding a gamma-distributed error term, $EXP(\varepsilon_i)$, with mean 1 and variance α^2 , to the Poisson model as shown here:

$$\lambda_i = EXP(\beta X_i + \varepsilon_i)$$

This error term allows the variance to differ from the mean as such:

$$Var[y_i] = E[y_i][1 + \alpha E[y_i]] = E[y_i] + \alpha E[y_i]^2$$

The Poisson model is regarded as a limiting case of the negative binomial model as α approaches zero. Consequently, selection between the two models is dependent upon the value of α . The negative binomial distribution has the form:

$$P(y_i) = \frac{\Gamma((1/\alpha) + y_i)}{\Gamma(1/\alpha) y_i!} \left(\frac{1/\alpha}{(1/\alpha) + \lambda_i} \right)^{\frac{1}{\alpha}} \left(\frac{\lambda_i}{(1/\alpha) + \lambda_i} \right)^{y_i},$$

where λ_i can be estimated by standard maximum likelihood methods.

A test for overdispersion, provided by Cameron and Trivedi (1990) is based on the assumption that under the Poisson model, $(y_i - E[y_i])^2 - E[y_i]$ has mean zero, where $E[y_i]$ is the predicted count $\bar{\lambda}_i$. Null and alternative hypothesis are generated, such that

$$H_0 : VAR[y_i] = E[y_i]$$

$$H_A : VAR[y_i] = E[y_i] + \alpha g(E[y_i]),$$

where $g(E[y_i])$ is a function of the predicted counts that is most often given values of

$$g(E[y_i]) = E[y_i] \text{ or } g(E[y_i]) = E[y_i]^2.$$

To conduct this test, a simple linear regression is estimated where Z_i is regressed on W_i , where

$$Z_i = \frac{(y_i - E(y_i))^2 - y_i}{E(y_i)\sqrt{2}}, \text{ and}$$

$$W_i = \frac{g(E(y_i))}{\sqrt{2}}.$$

After running the regression, $Z_i = bW_i$, if b is statistically significant in either case, then H_0 is rejected for the associated function g . In this instance, it may be concluded that random sampling does not satisfactorily explain the magnitude of the overdispersion parameter, and a Poisson model is rejected in favor of a negative binomial model (Washington et al., 2003).

Due to the possibility of zero-inflated count processes, the zero-inflated Poisson (ZIP) model is able to address the limitations imposed on the traditional Poisson model. The zero-inflated Poisson (ZIP) assumes two different processes are at work for some zero accident count data. The zero-inflated Poisson (ZIP) assumes the events, $Y = (Y_1, Y_2, \dots, Y_n)'$, are independent and produces the model:

$$Y_i = 0 \text{ with probability } p_i + (1 - p_i)e^{-\lambda_i}$$

$$Y_i = y \text{ with probability } \frac{(1 - p_i)e^{-\lambda_i} \lambda_i^y}{y!}, y = 1, 2, \dots$$

where y is the number of crashes. The mean and variance of Y_i can be shown to be:

$$E(Y_i) = (1 - p_i) \lambda_i^{y_i},$$

$$Var(Y_i) = E[Y_i] + \frac{p_i}{1 - p_i} E[Y_i]^2.$$

The zero-inflated negative binomial (ZINB) regression model follows a similar formulation to the zero-inflated Poisson (ZIP). It again assumes that the events, $Y=(Y_1, Y_2, \dots, Y_n)'$, are independent and the model is:

$$Y_i=0 \text{ with probability } p_i + (1 - p_i) \left[\frac{1/\alpha}{(1/\alpha) + \lambda_i} \right]^{1/\alpha}$$

$$Y_i=y \text{ with probability } (1 - p_i) \left[\frac{\Gamma((1/\alpha) + y) \mu_i^{1/\alpha} (1 - \mu_i)^y}{\Gamma(1/\alpha) y_i!} \right],$$

$$\text{where } \mu_i = \frac{\left(\frac{1}{\alpha} \right)}{\left(\frac{1}{\alpha} + \lambda_i \right)}.$$

The choice of an appropriate form of the model is critical in cases where the zero-accident state may exist. Choosing an appropriate model is problematic, though, because a direct test cannot be done to determine if the zero-accident state and non-zero accident state are totally different. This is due to the fact that the traditional and zero-inflated models are not nested. Vuong (1989) developed a test statistic for non-nested models that is well-suited for this setting when the distribution can be specified.

For Vuong's statistic, let $f_j(y_i|x_i)$ be the predicted probability that the random variable Y equals y_i under the assumption that the distribution is $f_j(y_i|x_i)$, for $j=1,2$, and let

$$m_i = \log \left(\frac{f_1(y_i | x_i)}{f_2(y_i | x_i)} \right)$$

where:

$f_1(y_i|x_i)$ is the probability density function of the zero-inflated model, and

$f_2(y_i|x_i)$ is the probability density function of the Poisson or negative binomial distribution.

Vuong's statistic for testing the non-nested hypothesis of zero-inflated model versus traditional model is:

$$v = \frac{\sqrt{n} \left[(1/n) \sum_{i=1}^n m_i \right]}{\sqrt{(1/n) \sum_{i=1}^n (m_i - \bar{m})^2}} = \frac{\sqrt{n}(\bar{m})}{S_m}$$

where:

\bar{m} is the mean,

S_m is standard deviation, and
 n is a sample size.

Vuong's value is asymptotically standard normally distributed, and if $|v|$ is less than 1.96 (the 95 percent confidence level for the t-test), the test does not indicate any other model. However, the zero-inflated regression model is favored if the v value is greater than 1.96, while a v value of less than -1.96 favors the Poisson or negative binomial regression model.

When developing the models for crash frequency, negative binomial models were developed in all cases. Poisson models were not used because of the inherent danger of incorrectly specified coefficients due to the lack of an overdispersion term. Even if the α term is relatively small, the parameter still has practical value.

The presence of a zero-count state was tested for by using Vuong's test statistic. A Vuong statistic of greater than 1.96 favors a zero-altered form of the model, while a value of less than -1.96 favors the traditional model form.

3.4.3. Severity Analysis

The severity of an accident is typically measured as the level of injury sustained by the most severely injured vehicle occupant (Chang and Mannering, 1999). In Indiana, accident severity is classified as property damage only (PDO), injury (I), or fatal (F). As such, the severity level is a discrete outcome. An appropriate method of modeling such data is the multinomial logit model (MNL).

Multinomial logit models are used to estimate the probability that vehicular accident n is severity i by determining the likelihood of discrete outcomes given that an accident has occurred. Mathematically stated,

$$P_n(i) = P(S_{in} \geq S_{ln}) \quad \forall I \neq i,$$

where $P_n(i)$ is the probability that a discrete outcome i (accident severity category i) occurs in an accident n , where P denotes probability and S_{in} is a function that determines the severity of accident n . The severity function takes the linear form shown below:

$$S_{in} = \beta_i X_n + \varepsilon_{in},$$

where β_i is a vector of statistically estimable coefficients, X_n is a vector of measurable characteristics that determine severity, and ε_{in} is a disturbance term influencing accident severity independent of each severity category. By assuming that the disturbances are generalized

extreme value (GEV) distributed, a multinomial logit (MNL) model can be derived to estimate the probability of accident severity (McFadden, 1981),

$$P_n(i) = \frac{\exp[\beta_i X_n]}{\sum_j \exp[\beta_j X_n]},$$

where all variables are as previously defined and the coefficient vector β_i is estimable by standard maximum likelihood techniques.

3.4.4. Binomial Test for Comparison of Proportions

A number of variables could not be included in the crash frequency models due to a lack of complete information. Such variables included lighting, weather, and pavement conditions. While these parameters are known at the time of each crash, there is no way to accurately determine the same parameters during periods when there are no crashes. However, the effect of such elements in relation to curvature can be obtained in another way by using the crash-specific information available in the Indiana crash database.

By selecting two intersection samples, a comparison can be made between the proportions of crashes in each sample that occur under certain conditions. These proportions can then be compared and if they are significantly different, it can be claimed that the sample with the higher proportion is overrepresented. The crash database was used to select two separate samples, one for intersections on curves and another for intersections on tangents. The first sample consisted of the 244 crashes that occurred on curves along four-lane highways. This is the same sample used in the four-lane safety analysis (Chapter 5). Note that the complete four-lane sample consisted of 258 intersections. The remaining 14 crashes from this sample were used in the second sample. This second sample consisted of all crashes occurring at tangent intersections along the same divided four-lane highways. The intersections included in this sample were selected by searching the crash database by major road and county. Aerial photos of the intersection were then examined to determine if the selection criteria were met (four-lane divided highway, rural, unsignalized). The final tangent sample contained 2,180 crashes.

The database was then used to extract lighting, weather, and pavement conditions for all crashes in the two samples. By comparing the proportion of crashes related to each variable between the two samples, it can be determined if a variable is overrepresented or underrepresented for the intersections on curves. For example, if the proportion of the crashes on curves during dark conditions is significantly greater than the proportion for the tangent

sample, the curved case is overrepresented. It can then be concluded that the combination of curvature and darkness make the intersections from the first sample more hazardous. For these types of variables, the appropriate comparison is made by testing whether the proportion of crashes between the two distinct groups is equal.

The appropriate statistical test is performed using the binomial distribution. Our best estimate of the true proportion of crashes occurring at intersections on curves, or likelihood of success in the binomial meaning, is:

$$s = \frac{C}{C + T}$$

where

C = the total number of crashes at intersections located on curves

T = the total number of crashes at intersections located on tangents.

Using this estimate of the true proportion, we can check if the number of crashes on curves, C_k of a particular category k (night, right-angle, injuries, etc.) is underrepresented or overrepresented in the number of crashes at significance level f. This is done by calculating the binomial likelihood, $P(X \leq C_k)$, given the number of trials, $(C_k + T_k)$, likelihood of success, $s_k = s$, and the number of successes, C_k . If the likelihood is smaller than f, then the category k is underrepresented, implying that the true likelihood of success s_k is lower than s. Similarly, if the likelihood is larger than 1-f, then the category is overrepresented. A threshold f-value of 0.10 was used for this analysis.

CHAPTER 4. SAFETY ANALYSIS OF INTERSECTIONS ALONG TWO-LANE ROADS

A safety analysis was conducted to determine whether intersections on curves experienced a higher number of crashes than similar intersections located on tangents for cases where both routes are two-lane roads. This analysis focused on the intersection of high-speed rural two-lane highways. Intersections were selected only along state and U.S. routes as more complete data was readily available for such intersections. This eliminated the need for possible field data collection of traffic and crash data as such information was available directly from the state for these intersections.

4.1. Intersection Selection

The initial group of intersections was selected using an Indiana state atlas and county flow maps obtained from the INDOT website (<http://www.in.gov/dot/div/traffic/count/index.html>). When selecting the intersections, an attempt was made to pair groups of intersections on tangents and curves with similar traffic and geometric characteristics located along the same major roads where possible. This would produce two samples of equal number similar in most respects with the exception of curvature. However, it was not possible to find suitable pairs in many instances, particularly along the same major road because in rural areas such intersections are typically not in close proximity to one another. For this reason, two separate groups of intersections were instead selected, one for curved sections and one for tangent sections. The reason for the selection of the two groups was that direct comparisons could be made between them to determine if there was a significant difference between those on curves and tangents in general. The initial search produced 27 possible intersections of state-state roads on curves. After initial selection, the intersections were verified to ensure they met the study criteria using images supplied by the U.S. Geological Survey. A sample photo is shown in Figure 4-1. From the original 27 intersections located on curves, 9 were removed for one of two reasons:

- The intersections occurred on a major road that was a four-lane highway. Such intersections were excluded from this sample because four-lane divided highways are inherently different from two-lane highways. The four-lane case was examined in a separate analysis.

- The intersections had been realigned over the course of the study period. The county flow maps revealed a number of intersections had been realigned at some point between 1997 and 2000. Since crash data was only available for this time period, such intersections had to be removed from the sample because it could not be determined which crashes occurred with which alignment.



Figure 4-1 Sample Aerial Photo (Source: <http://www.mapquest.com>)

In addition to the 18 intersections on curves, 85 additional intersections on tangents were used to constitute the remainder of the sample. Crash and traffic data was already compiled for a large number of these intersections from a previous research project by Tarko and Kanodia (2004). The final sample for the two-lane study consisted of 103 intersections. The list of 18 intersections located on curves is shown in Table 4-1.

4.2. Volumes

After the intersections were selected, traffic volumes for each were obtained from INDOT county flow maps. A sample flow map is shown in Figure 4-2.

INDOT conducts traffic counts every three to five years along all state routes. As such, at least two years of volume data was available for each intersection in the sample. Average Annual Daily Traffic (AADT) values for each leg of the intersection were taken directly from the flow maps for each corresponding year. The volumes for each intersection were derived by summing the volumes of each approach and dividing by two. The resulting volume represents

the total volume of vehicles entering the intersection per day. This was based on the assumption that traffic was evenly distributed in both directions on each approach. This same approach was used for each year for which traffic data was available at each intersection. Linear interpolation was then used to bring all traffic volumes to the same year. The yearly traffic in the year 1999 was used in the analysis as it fell in the middle of the period covered by the crash data available. An example calculation is illustrated in Table 4-2 for the intersection of State Road 37 and State Road 54/58 in Lawrence County. An aerial photo of the intersection is shown in Figure 4-3.

Table 4-1 List of Intersections on Curves (2-lane Case)

Major Road	Minor Road	County	District
SR-38	SR-39	Clinton	Crawfordsville
SR-64	SR-145	Crawford	Vincennes
SR-145	SR-164	Crawford	Vincennes
US-52	SR-46	Dearborn	Seymour
SR-48	SR-148	Dearborn	Seymour
US-52	SR-121	Franklin	Seymour
SR-54	SR-445	Greene	Vincennes
SR-37	SR 213	Hamilton	Greenfield
SR-64	SR-335	Harrison	Seymour
SR-11	SR-337	Harrison	Seymour
SR-62	SR-250	Jefferson	Seymour
SR-19	SR-10	Kosciusko	Fort Wayne
US-50	SR-60	Lawrence	Vincennes
US-50	US-150	Martin	Vincennes
SR-47	SR-59	Montgomery	Crawfordsville
SR-56/57	SR 356	Pike	Vincennes
US-27	US-36	Randolph	Greenfield
SR-256	SR-203	Scott	Seymour

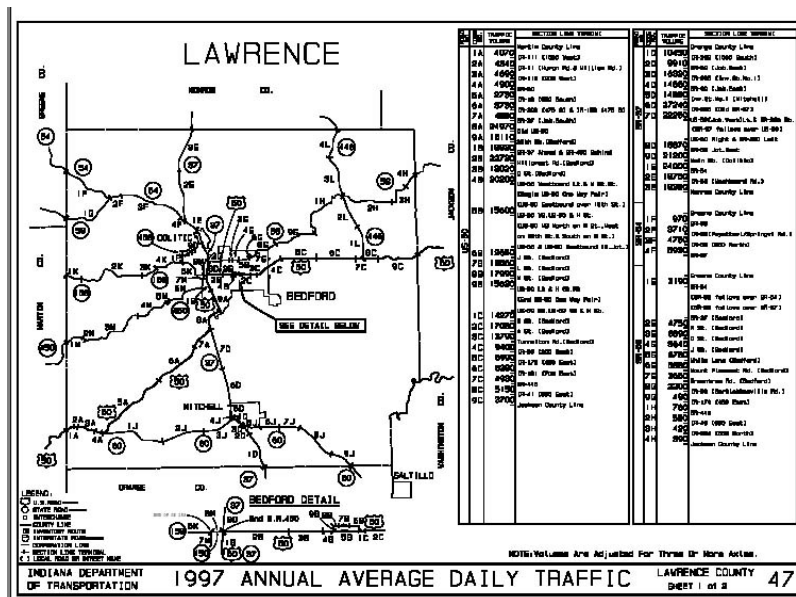


Figure 4-2 Sample Flow Map



Figure 4-3 Intersection of SR-37 & SR-54/58 (Source: <http://www.mapquest.com>)

The table shows AADT values for each of the three legs for the years 1997 and 2001 available from the INDOT flow maps. By interpolating between the two values, estimates are obtained for the target year, 1999.

Table 4-2 AADT Values for SR-37 & SR-54/58

APPROACH	AADT BY YEAR		
	1997	2001	1999
SR-37 NB	18750	19880	19315
SR-37 SB	24000	24840	24420
SR-54 WB	5930	6320	6125

The AADT value for SR-37 in this case would be the average of the northbound and southbound volumes for the forecast year. Through interpolation, the forecast year volumes for SR-37 are 19,315 vehicles per day for the northbound approach and 24,420 for the southbound approach. Averaging the volumes of each approach gives a final value of 21,868 vehicles per day. For the minor road, SR-54, the AADT would be 6,125. For four-legged intersections, the values for each approach of the minor road would be averaged to obtain the appropriate minor road AADT as was done for the major road.

4.3. Crashes

Upon completion of traffic volume estimation, crashes for the time period from 1997 to 2000 were extracted from the state crash database using Microsoft Access. The number and severity of all crashes at each intersection were obtained up to a threshold distance of one

hundred feet from the intersection. Similar data for the years 1997 to 1999 had already been obtained for a number of intersections in the aforementioned study by Tarko and Kanodia (2004), meaning only one additional year of data needed to be collected in these cases.

4.4. Degree of Curvature Approximation

Ideally, construction plans for each of the 18 intersections located on curves would have been used to obtain geometric data for each. However, such plans were not available for the majority of intersections in the sample. Field collection was looked at as an alternative. However, due to the intense resource demands, this was not a viable option for this analysis. It was necessary to obtain curvature information for each intersection in the sample, though.

For each of these intersections, the degree of curvature was approximated using geometric design templates. The approximation was done by taking aerial photographs of each site and scaling them up to a 1 inch equals 100 feet scale. The degree of curvature for each was then measured using the design templates. The values were measured to the nearest degree per 100-foot chord length. The list of intersections on curves and the corresponding degree of curvature values are included in Table 4-3.

4.5. Safety Evaluation

After obtaining traffic volumes, curvature, and crash data, statistical models were developed to determine the effect of curvature on crash frequency and severity.

Table 4-3 Range of D Values for Intersection Sample (2-lane Case)

Route 1	Route 2	County	D
US-50	US-150	Martin	15
SR-62	SR-250	Jefferson	12
SR-54	SR-445	Greene	12
SR-64	SR-145	Crawford	10
SR-11	SR-337	Harrison	10
SR-48	SR-148	Dearborn	10
US-52	SR-121	Franklin	6
SR-56/57	SR-356	Pike	5
SR-19	SR-10	Kosciusko	4
US-50	SR-60	Lawrence	4
SR-38	SR-39	Clinton	4
SR-256	SR-203	Scott	3
SR-64	SR-335	Harrison	3
US-52	SR-46	Dearborn	3
SR-145	SR-164	Crawford	3
SR-37	SR-213	Hamilton	3
US-27	US-36	Randolph	2
SR-47	SR-59	Montgomery	2

4.5.1. Crash Frequency Model

After obtaining traffic volumes, curvature, and crash data, LIMDEP was used to develop a negative binomial model to determine whether curvature had a significant impact on crash frequency. The negative binomial model takes the form:

$$C = K \cdot AADT_1^{\alpha_1} \cdot AADT_2^{\alpha_2} \cdot \exp(\beta_1 X_1 + \beta_2 X_2 + \dots + \beta_N X_N), \quad (4.1)$$

where:

C = expected # of crashes

AADT1 = average annual daily traffic on major road

AADT 2 = average annual daily traffic on minor road

K, α_1 , α_2 , β_1 , β_2 , β_N = constants

X_1 , X_2 , X_N = vectors of explanatory variables.

The Vuong test statistic was used to test for the presence of a zero-count state. The Vuong statistic was 1.851, indicating the unaltered negative binomial regression was more appropriate than a zero-inflated negative binomial model. The final model for curve effect is shown in Equation 4-2. The modeling results from LIMDEP are shown in Table 4-4, including variable explanations.

$$C = 0.0004 * AADT_1^{0.66} * AADT_2^{0.54} * \exp(0.37 FLASH - 0.03D) \quad (4.2)$$

Table 4-4 Results of Negative Binomial Model for Curve Effect

Negative Binomial Regression					
Maximum Likelihood Estimates					
Negative Binomial Regression					
Maximum Likelihood Estimates					
Dependent variable		CRASH			
Weighting variable		ONE			
Number of observations		104			
Log likelihood function		-267.6686			
Restricted log likelihood		-314.6434			
Variable	Explanation	Coeff.	Std.Err.	t-ratio	P-value
ONE	Constant	-7.7388	1.1846	-6.5329	0.0000
ADT1	AADT on Major Road	0.6639	0.1668	3.9801	0.0001
ADT2	AADT on Minor Road	0.5365	0.1262	4.2512	0.0000
FLASH	Flasher Indicator Variable	0.3744	0.1637	2.2874	0.0222
D	Degree of Curvature	-0.0353	0.0185	-1.9068	0.0566
Alpha	Overdispersion Parameter	0.3477	0.0819	4.2435	0.0002

The results of the model show increasing ADT and the presence of a flasher to be associated with an increase in crash frequency. Clearly, as traffic increases, frequency will increase as well due to the increase in potential conflicts. The positive coefficient for the FLASH variable may seem counterintuitive. However, the results do not mean that flashers increase the number of accidents at a location. The coefficient is positive because flashers are typically installed at high-crash locations to warn drivers of a potential hazard. The degree of curvature variable also provides counterintuitive results. The coefficient on this variable was negative, indicating the intersections on curves had less crashes on average than those on tangents. Based on this result, there does not appear to be a safety problem associated with curvature for intersections where both routes are two-lane roads. This finding has to be taken with a caution due to the limited number of intersections on curves considered.

4.5.2. Crash Severity Model

In addition to examining crash frequency, the crashes in the sample were examined to determine whether curvature played a role in increasing the severity of an accident. A multinomial logit (MNL) model was developed, where the probability of an injury or fatal accident is given by:

$$P(I/F) = \frac{e^{S_{I/F}}}{1 + e^{S_{I/F}}}, \quad (4.3)$$

where $S_{I/F}$ is the severity function:

$$S_{in} = \beta_i X_n + \varepsilon_{in}. \quad (4.4)$$

The parameters β_i and ε_{in} are constant terms and X_n is a vector of explanatory variables. As the severity function is increased, the likelihood of a severe crash increases. For the 815 crashes in the sample, the modeling process resulted in Equation 4.5.

$$S_{I/F} = -0.02D + 0.54FOURLEG + 0.02FLASH - 0.85, \quad (4.5)$$

where:

D = degree of curvature (degrees per 100-ft chord length),

FOURLEG = four-legged intersection indicator variable

FLASH = flasher presence indicator variable.

Positive coefficients indicate a variable tends to make crashes more severe as it is increased. Conversely, a negative sign indicates that crashes tend to become less severe as the variable is increased. The model shows crashes to be less severe at three-legged intersections. This may be due to the fact that there are fewer right-angle collisions in comparison to four-legged intersections because of fewer possible conflict points. Flasher installation has a slight tendency to be associated with more severe crashes. Degree of curvature again has a negative coefficient, indicating crashes tend to be less frequent and less severe at the intersections in the sample.

From the results of the study, it was not possible to confirm a negative impact of curvature on intersection safety for the case where both routes are two-lane roads. However, additional research may be helpful as the sample size for this study was relatively small, with only 18 intersections located on curves. Due to the small sample size, the results may be an indicator of randomness within the data rather than an actual trend.

CHAPTER 5. SAFETY ANALYSIS OF INTERSECTIONS ON FOUR-LANE ROADS

A safety analysis was conducted to determine whether intersections on curves experienced a higher number of crashes than similar intersections located on tangents for the case where the mainline road is a four-lane divided highway. The secondary roads were again two-lane with stop-control on each leg. County and local roads were included in this sample due to the small number of state-state intersections fitting the study criteria.

The intersection serving as the primary motivation for this study is that of US-31 and SR-14. It is the most notable of the cases where intersections on curves along four-lane divided highways have raised safety concerns. The intersection is located near Rochester, IN. Over a period from 1986 to 1992, the intersection experienced 103 crashes, 87 of which were right-angle collisions. The yearly crash data for the intersection over this period is shown in Table 5-1.

Table 5-1 Crash Data for Intersection of US-31 and SR-14

Year	Total Crashes	Right-Angle Crashes
1986	15	14
1987	21	17
1988	21	14
1989	21	19
1990	15	13
1991	6	6
1992	4	4
Total	103	87

Due to the recurring accidents, the following geometric changes were implemented at the intersection:

- Flexible delineators were added to the islands on the right turn lanes off of US-31.
- Strobes were installed in the "Flashing Beacon".
- "Rumble Strips" were added on US-31, approaching SR-14 from each direction.
- The word message pavement marking "STOP" was added prior to the signs on SR-14.
- The stop bars on the minor road were relocated closer to the mainline in an attempt to reduce the required crossing time.

Due to these changes, there was a considerable reduction in crashes during the years 1990 and 1991. However, safety concerns remained and, in the fall of 1992, a comprehensive engineering investigation was conducted at the intersection to determine whether signalization was warranted. Signalization was denied because the minimum volume portion of MUTCD Warrant 7 (USDOT, 2001) was not satisfied. The intersection was instead channelized to restrict left-turns on the southbound approach. Crossing movements between the minor roads were also restricted. The intersection currently allows only northbound vehicles to enter the median. Recent accident data for the years 1997 through 2000 are shown in Table 5-2:

Table 5-2 Crash Data for Intersection of US-31 and SR-14

Year	Total Crashes	Right-Angle Crashes
1997	0	0
1998	2	1
1999	1	0
2000	4	0
Total	7	1

As expected, the channelization and median treatment produced a significant reduction in the number of crashes, particularly right-angle collisions. However, this median treatment requires traffic on the southbound, eastbound, and westbound approaches to find an alternate route. To accommodate these movements, a grade separation is currently programmed for construction in the near future. However, such a solution is costly to both INDOT and travelers. The purpose of the four-lane study was to determine more effective ways of dealing with such intersections if they are, in fact, more dangerous than similar tangents.

5.1. Intersection Selection

Intersections were selected in coordination with the Indiana Department of Transportation district offices. The two-lane analysis focused exclusively on state-state intersections. However, for the four-lane analysis, intersections with county and local roads were included because only seven state-state intersections fit the criteria. A preliminary list of intersections was prepared from a State atlas and the county flow maps as was done in the analysis of two-lane roads. The list was then sent to each of the six INDOT districts to verify whether or not each intersection listed met the criteria for the study. For an intersection to be selected, a number of criteria had to be met. The major road had to be a rural, divided, non-freeway highway located on a curve. The minor road was required to have two-way stop-control.

Additions and deletions were made to the initial list by the district offices and a final list was compiled and used to plan field data collection. This list included 52 intersections located on curves. Over the course of the data collection, additional intersections were removed from the study because they did not fit our criteria and had been selected erroneously. The final sample consisted of 43 intersections on curves and 6 intersections on tangents. Table 5-3 shows this final list of intersections under analysis.

Due to the relatively small sample size, the Highway Safety Information System (HSIS) was looked at as an option for collecting similar data for other states in the Midwest to verify the results obtained from our analysis. Vogt and Bared (1998) used the HSIS extensively in their studies of two-lane rural roads. The HSIS is a database that contains crash, roadway inventory, and traffic volume data for a select group of states. Past research has shown a number of drawbacks associated with using the HSIS. Some of the crash data is questionable due to underreporting and classification problems. For instance, Michigan has a large number of crashes reported without an officer on the scene. Additionally, some cases exist where crashes are attributed to the wrong intersection. A further problem is that the same information is not available for all states. Some necessary geometric characteristics could not be obtained from the database. Due to these potential complications, the HSIS was not used for this research.

5.2. Volumes

Volumes for the primary roads were collected from county flow maps as described in Section 4.2. Volumes for the secondary roads fell into one of two categories: state roads and local/county roads. Data for state roads were obtained in the same manner as for the primary roads.

Similar count data was not available for non-state roads. For intersections where the minor road was a local or county road, two-hour traffic counts on the non-state roads were done from May through July of 2003. The counts were conducted during peak traffic periods when possible. The number of vehicles entering and exiting the minor road was recorded at each intersection for each of the ten traffic movements illustrated in Figure 5-1. Through, left-turning and right-turning traffic counts were done for each minor approach. Additionally, left-turns and right-turns from the major road onto the minor road were recorded. The number of heavy vehicles was not recorded because there were very few observed at the sample intersections, particularly for the local roads.

Table 5-3 Intersections Under Analysis (4-lane Case)

Major Road	Minor Road	County
US-41/52	CR 600 W.	Benton
US-41/52	CR 700 N.	Benton
US-52	SR-352 / CR 600 S.	Benton
US-52	CR 600 E.	Benton
US-36	CR 571 E. / CR 575 E.	Hendricks
SR-63	SR-71	Vermillion
SR-63	Market Street	Vermillion
SR-63	Barnhart Road	Vigo
SR-63	SR-263 North Jct.	Warren
SR-63	SR-263 South Jct.	Warren
SR-63	Division Road	Warren
US-31	CR 300 S.	Fulton
US-31	9A Road	Marshall
US-31	Tyler Road	Marshall / St. Joseph
US-31	Quinn Trail	St. Joseph
US-50	Stoops Road	Dearborn
US-50	Texas Gas Road	Dearborn
US-50	SR-262 / Station Hollow	Dearborn
US-421	Old SR-62	Madison
SR-37	Victor Pike	Monroe
SR-37	Burma Road	Monroe
SR-67	SR-39 North Jct.	Morgan
SR-67	Centerton Road / Rob Hill Road	Morgan
US-50/150	CR 300 W.	Daviess
US-50/150	SR-257	Daviess
US-41	CR 1025 S.	Gibson
US-41	CR 150 S.	Gibson
US-41	CR 350 N.	Gibson
US-41	SR-56	Gibson
US-41	Old US-41	Gibson
US-41	CR 575 N.	Gibson
US-41	CR 550 W.	Knox
US-41	SR-241	Knox
US-41	CR 500 W.	Knox
US-41	CR 1000 N.	Knox
US-41	CR 1100 NE.	Knox
US-41	SR-550	Knox
US-50	CR SE 500 E.	Knox
US-50	CR SE 900 E.	Knox
SR-37	SR-54/58	Lawrence
SR-37	CR 475 N.	Lawrence
US-41	CR 400 S.	Sullivan
US-41	CR 200 N.	Sullivan
US-41	CR 575 N.	Sullivan
US-41	Radio Ave.	Vanderburgh
US-41	Campbell Road / Old State Road	Vanderburgh
SR-62	Posey County Line Road	Posey / Vanderburgh
SR-62	McDowell Road	Vanderburgh
SR-66	St. Joseph Road	Vanderburgh

Bold font denotes tangent intersections

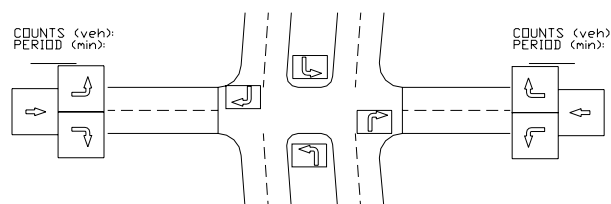


Figure 5-1 Traffic Movements Counted

The final counts were converted to AADT values in a three-step process. The two-hour counts were first converted to 24-hour volumes by using the hourly factors shown in Table 5-4. The hourly adjustment factors were determined by selecting a sample of sixty county roads from the Tippecanoe County Highway Department (TCHD) traffic records. The TCHD records 24-hour volumes at each county road within the system at least once every five years. Intersections were selected with similar hourly volumes to the data for this study. It was assumed that volume variability in Tippecanoe County was representative of the entire state. The hourly factors are used to convert one-hour counts to AADT counts. The bi-hourly factors are the averages of consecutive hourly factors. Multiplying the number of vehicles counted by the bi-hourly factor gives the approximation of AADT.

Table 5-4 AADT Hourly & Bi-hourly Factors

Hour Beginning	Percent of Total 24-Hour Volume	Hourly Factor	Bi-hourly Factor
6:00 AM	4.40%	22.73	8.37
7:00 AM	7.55%	13.25	7.78
8:00 AM	5.31%	18.83	10.17
9:00 AM	4.52%	22.12	11.12
10:00 AM	4.47%	22.37	10.65
11:00 AM	4.92%	20.33	9.75
12:00 AM	5.34%	18.73	9.73
1:00 PM	4.94%	20.24	9.19
2:00 PM	5.94%	16.84	7.63
3:00 PM	7.16%	13.97	6.31
4:00 PM	8.70%	11.49	5.61
5:00 PM	9.14%	10.94	6.27
6:00 PM	6.80%	14.71	8.29
7:00 PM	5.27%	18.98	10.22
8:00 PM	4.51%	22.17	12.85
9:00 PM	3.27%	30.58	18.18
10:00 PM	2.23%	44.84	27.25
11:00 PM	1.44%	69.44	44.25
12:00 PM	0.82%	121.95	81.97
1:00 AM	0.40%	250.00	144.93
2:00 AM	0.29%	344.83	185.19
3:00 AM	0.25%	400.00	131.58
4:00 AM	0.51%	196.08	42.92
5:00 AM	1.82%	54.95	16.08

Next, the daily counts were adjusted for the day of the week on which the counts were taken. The TCHD provided the data in Table 5-5, which is used by the department to adjust their count data based on the day the count is taken. The appropriate weekly factor is multiplied by the value obtained from the previous step.

Table 5-5 AADT Weekly Factors

Day	Percent of Total Weekly Volume	Percent of Average Day	Weekly Factor
Sunday	18.10	126.73	0.79
Monday	13.32	93.25	1.07
Tuesday	12.75	89.14	1.12
Wednesday	12.89	90.22	1.11
Thursday	13.00	91.04	1.10
Friday	14.06	98.44	1.02
Saturday	15.88	111.18	0.90

The final step in converting the traffic volumes was to adjust for the month in which the count was taken. The adjusted AADT from the previous step is multiplied by a monthly factor from Table 5-6 to arrive at the final estimated AADT value. The equation for converting the two-hour counts to AADT counts is then:

$$\text{AADT} = (\text{Two-hour count data})(\text{Bi-hourly Factor})(\text{Weekly Factor})(\text{Monthly Factor})$$

Table 5-6 AADT Monthly Factors

Month	Percent of Average Month	Monthly Factor
January	82.24	1.22
February	83.94	1.19
March	90.89	1.10
April	100.79	0.99
May	105.29	0.95
June	108.89	0.92
July	109.51	0.91
August	113.38	0.88
September	113.10	0.88
October	107.46	0.93
November	97.38	1.03
December	87.13	1.11

time required. The crossing time measurement is similar to the time gap (t_g) in AASHTO (2001), which is the time required by a vehicle to clear the major road. In this study, all intersections had a usable median. For that reason, the crossing time was defined to be the time required for a car to safely pass from the stop bar to the median. Crossing times were measured using a stopwatch. Measurements were obtained by manually performing the crossing maneuver and recording the time required. All times were recorded to the nearest hundredth of a second. Five measurements were taken from each approach to the median. Three-legged intersections have one crossing time value and four-legged intersections have two. In general, both crossing times at four legged intersections were fairly close. Figure 5-3 shows the distances over which the crossing times were measured.

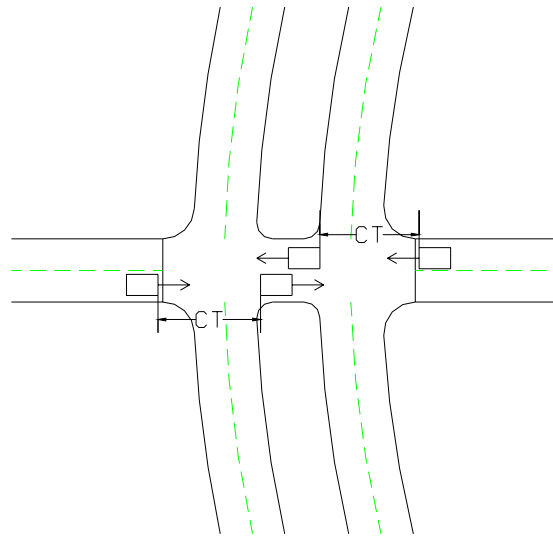


Figure 5-3 Crossing Times

The time available for crossing is defined here as the time a driver has to safely cross from stop bar to median. These times are based on sight distance at each of the four possible stopping points. These times were recorded using a stopwatch. The beginning of the time available for crossing is the moment when a vehicle first comes into the stopped driver's field of view. The end of the time available for crossing is the moment when the oncoming vehicle crosses the path between the stopped vehicle and the median. Figure 5-4 and Figure 5-5 detail the measured times in graphical form. Each time available for crossing was measured 10 times for each intersection. Two measurements were taken at each stop bar, one for traffic approaching from the left side and the other for traffic on the other side of the median approaching from the right side. Four-legged intersections had 60 total measurements and three-legged intersections had 40.

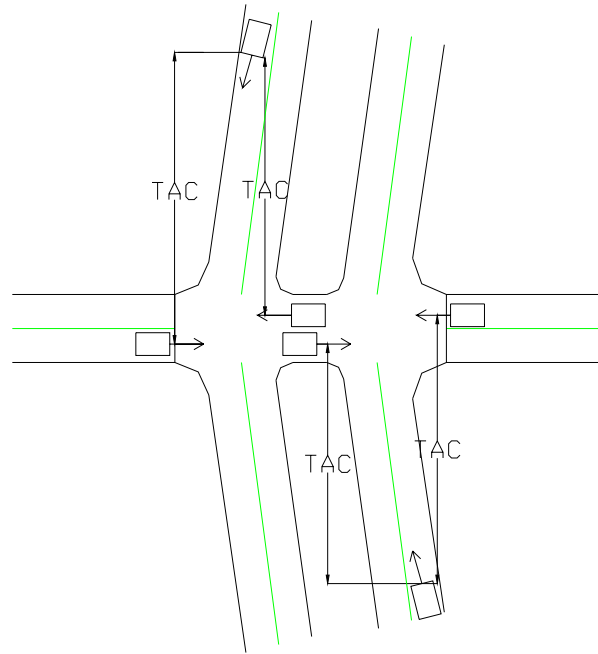


Figure 5-4 Time Available for Crossing to Median

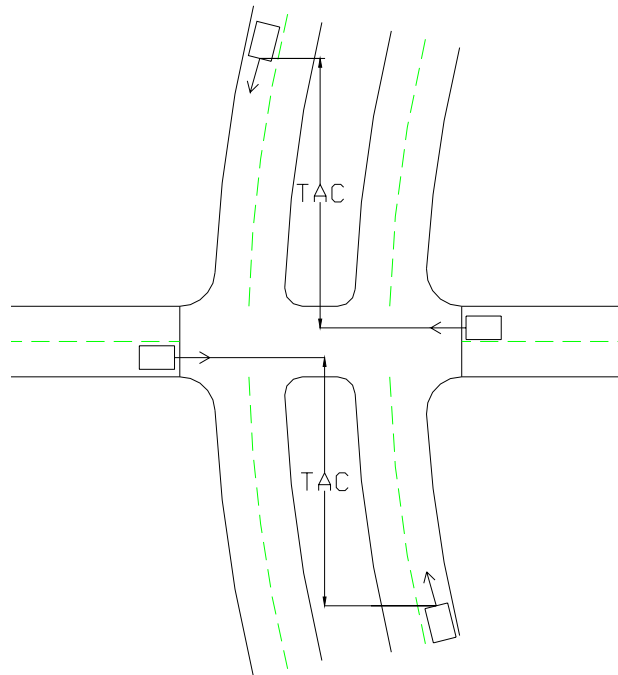


Figure 5-5 Time Available for Crossing Entire Roadway

Sight distance is a major concern of highway designers. As curvature and superelevation are introduced, sight distance may become restricted. Design standards require a minimum length for the leg of a clear sight triangle along the major road. AASHTO (2001) states “The sight distance should be equal to or greater than the minimum value for specific intersection conditions.”

To determine if the sight distance requirements were sufficiently met at each intersection, the measured times available for crossing were compared to the corresponding crossing times for each intersection. The difference between the crossing time and the time allowable for crossing is labeled marginal time available for crossing (MTAC). All 49 intersections in the sample met this minimum sight distance requirement for traffic crossing to and from the median.

However, there were some cases where the sight distance requirement was not met for vehicles attempting to cross the entire intersection. Two intersections resulted in negative MTAC values, indicating the available sight distance was less than the required sight distance.

For modeling purposes, the MTAC values for each case were transformed to develop the MTACINV variables shown below:

$$MTACINV = \frac{1}{MTAC} \text{ for crossing to and from the median,}$$

$$MTACINV2 = \frac{1}{MTAC + 5.5} \text{ for crossing the entire intersection.}$$

An additional 5.5 seconds are added to the MTAC for the second case so that the resulting value would be greater than zero. It was assumed the relationship was better explained using the inverse function rather than a direct linear relationship.

Figure 5-6 through Figure 5-11 show plots of available gap versus degree of curvature for each of the six cases where a vehicle attempts a crossing maneuver. As expected, the available gaps are shortest on the approach inside the curve and longest on the approach outside the curve with a few exceptions. However, there is no clear relationship between degree of curvature and available gap shown for any of the cases. Based upon these findings, curvature does not appear to be a cause of restricted sight distance along four-lane divided highways.

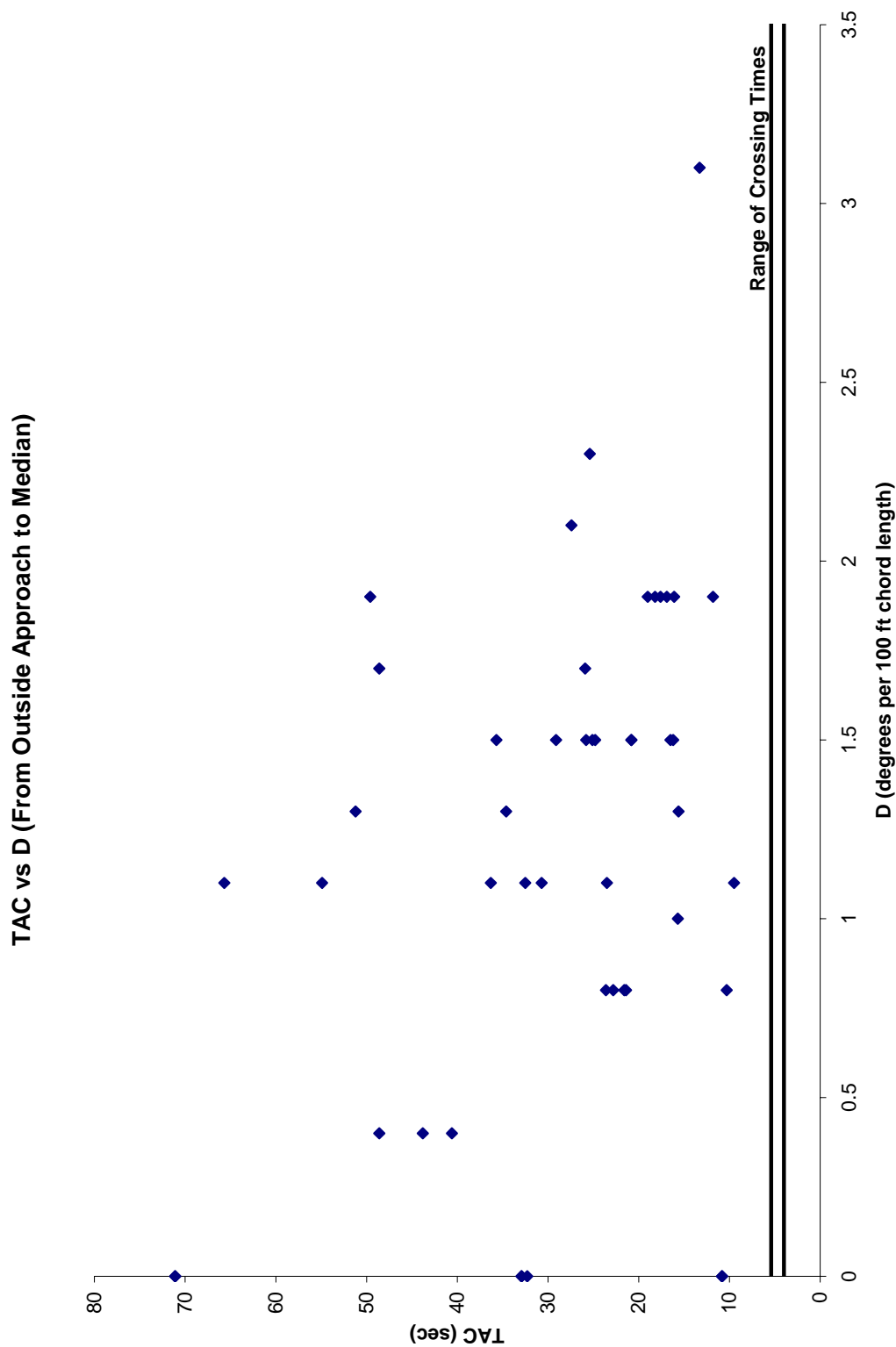


Figure 5-6 Time Available for Crossing vs. D (Outside Approach to Median)

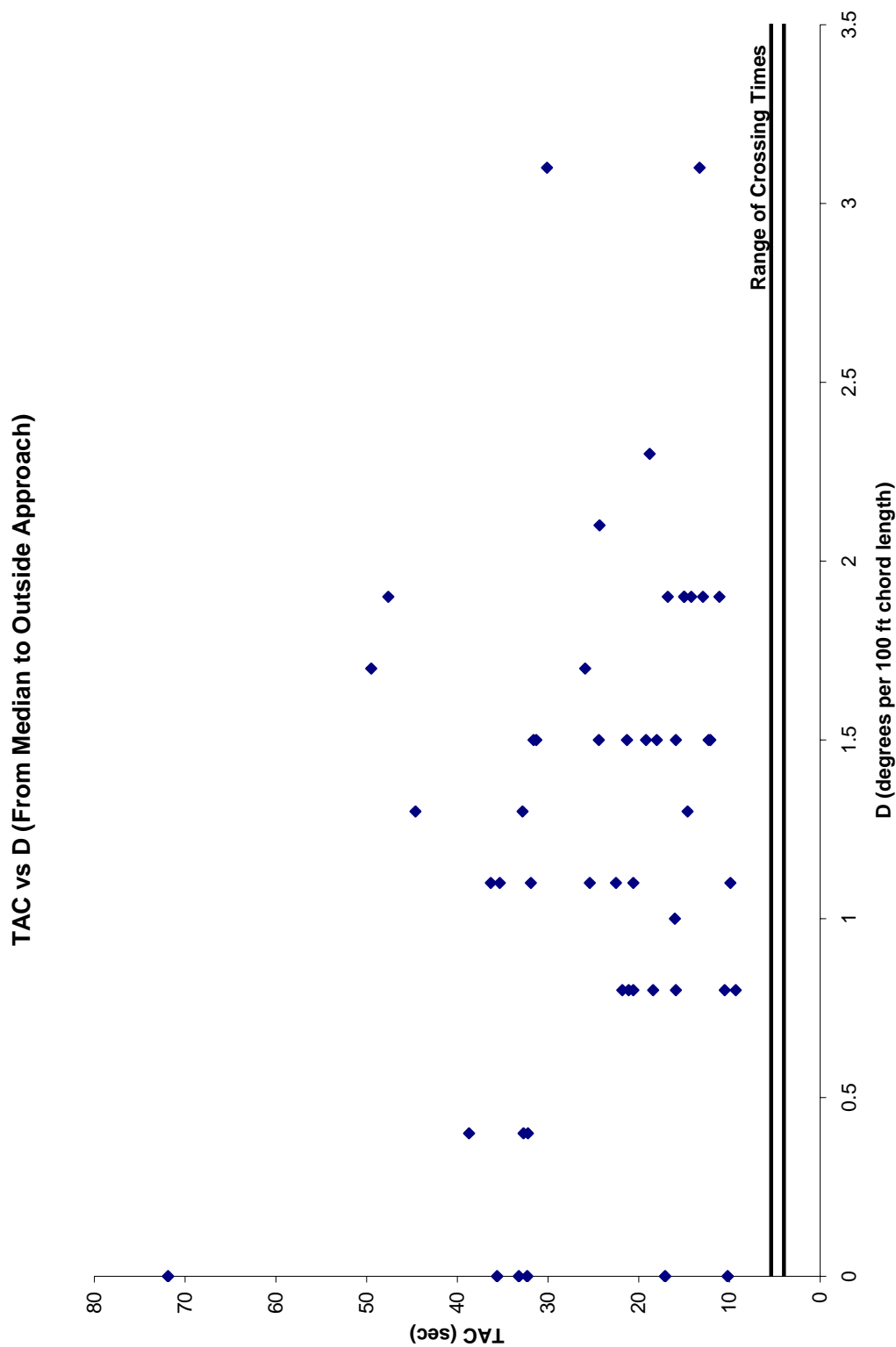


Figure 5-7 Time Available for Crossing vs. D (Median to Outside Approach)

TAC vs D (From Inside Approach to Median)

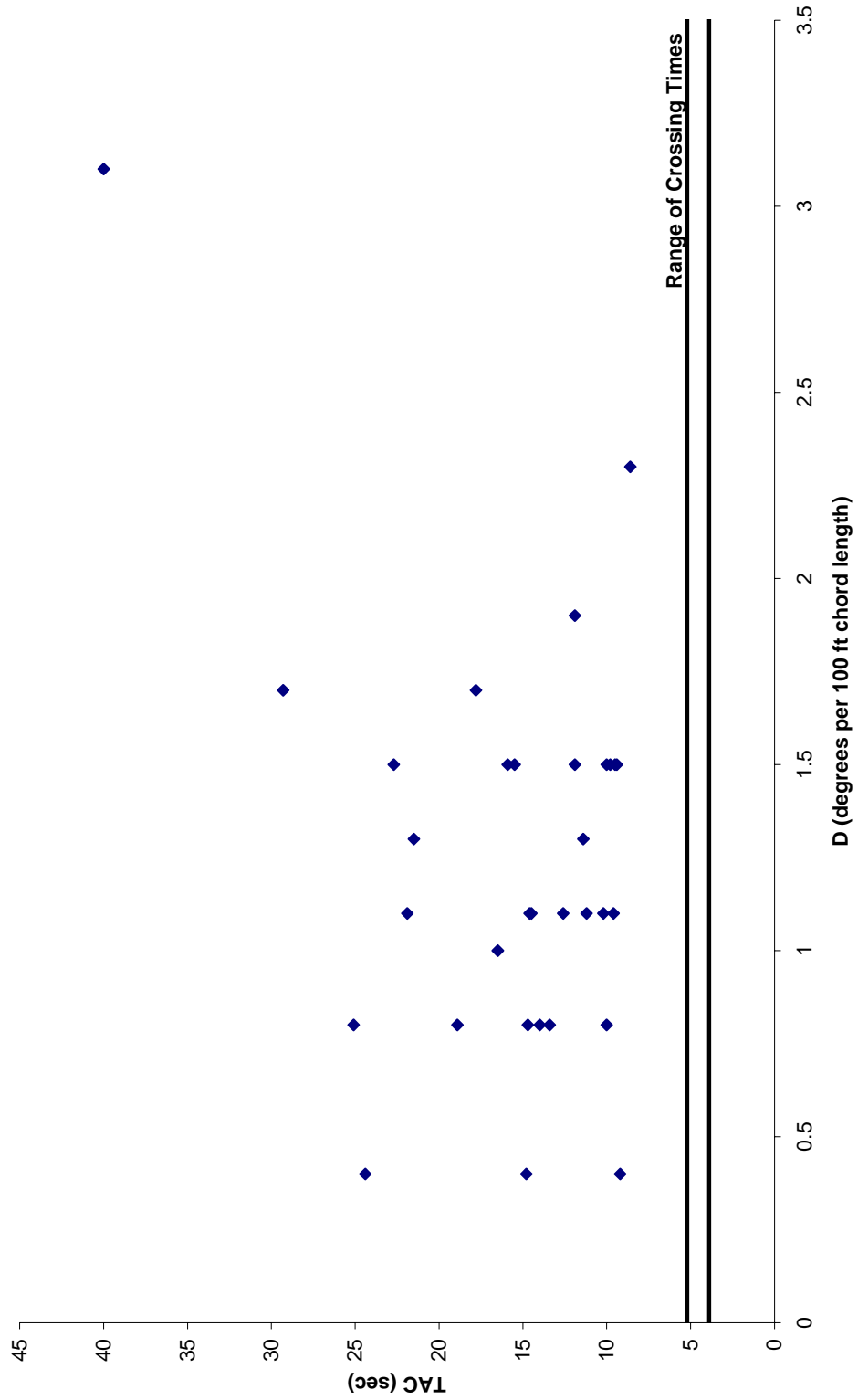


Figure 5-8 Time Available for Crossing vs. D (Inside Approach to Median)

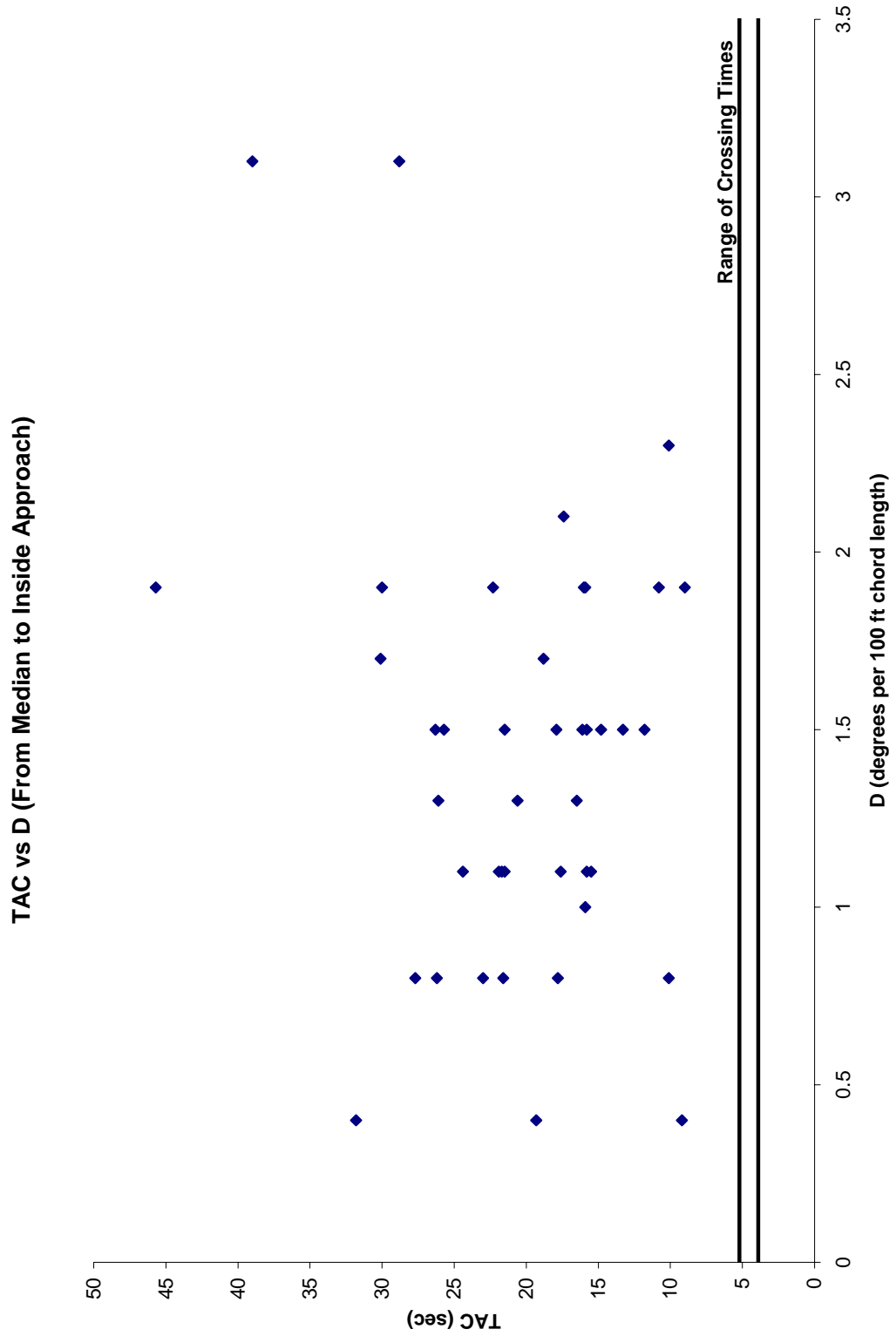


Figure 5-9 Time Available for Crossing vs. D (Median to Inside Approach)

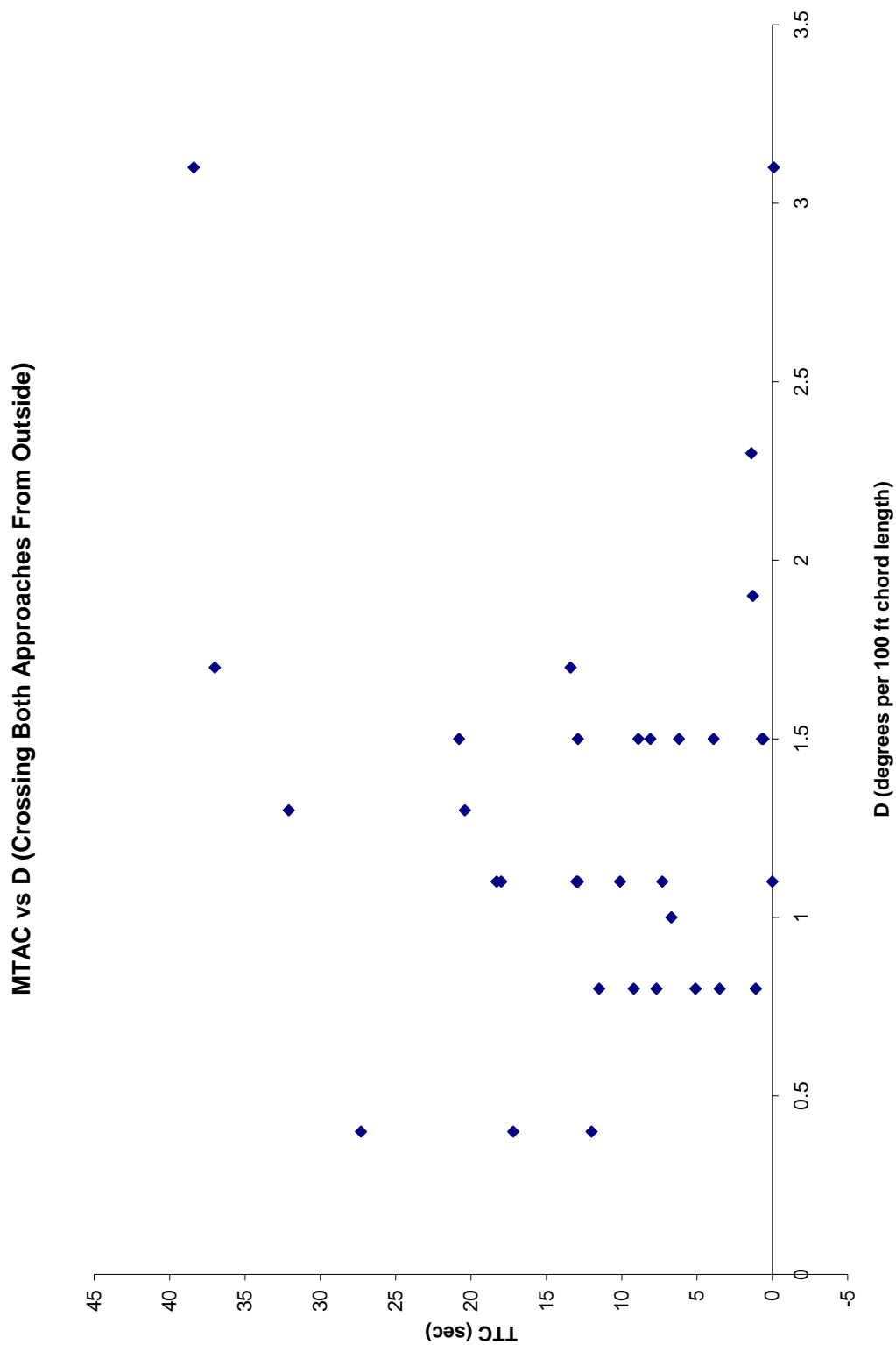


Figure 5-10 Marginal Time Available for Crossing vs. D (Both Approaches from Outside)

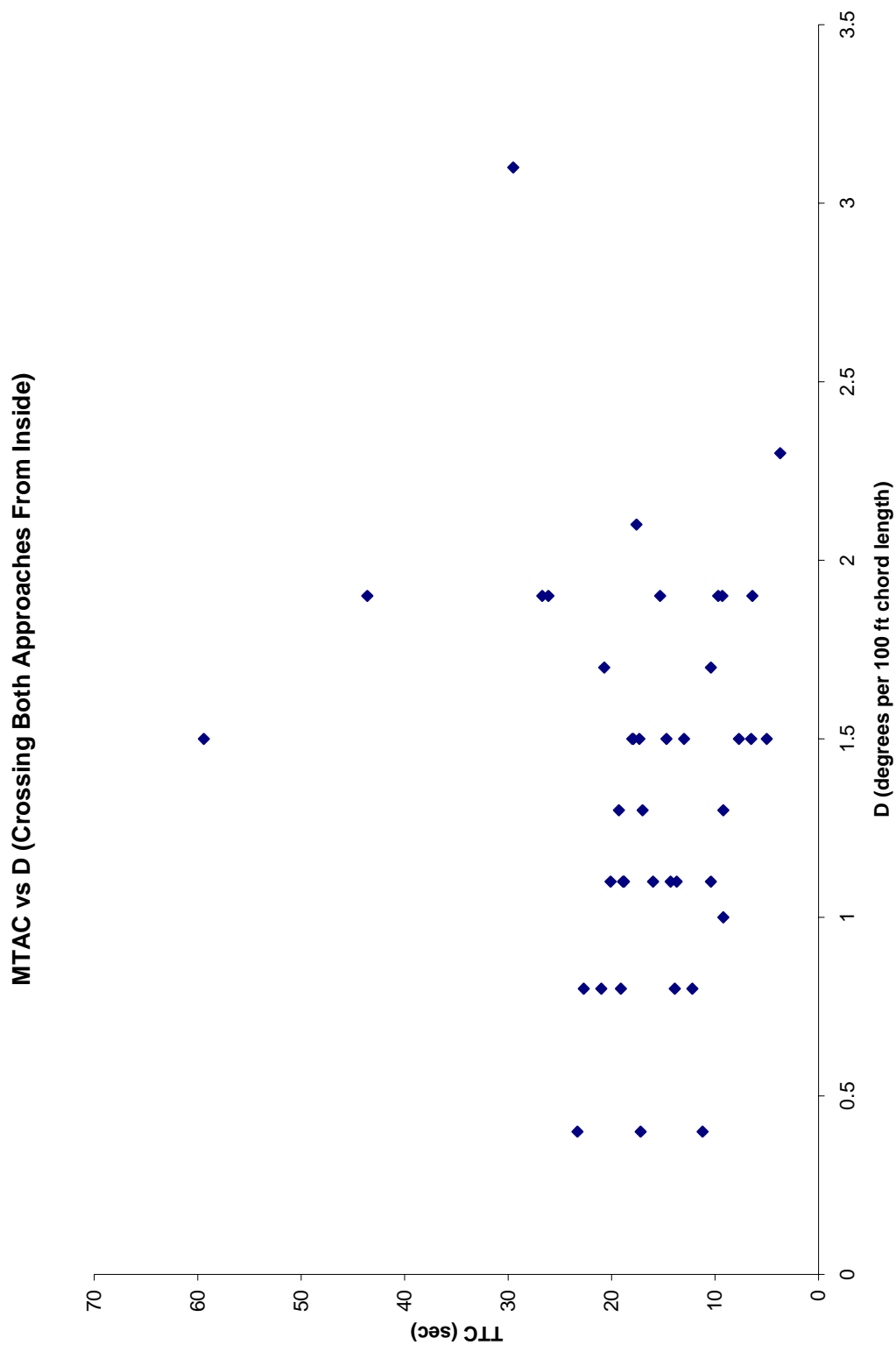


Figure 5-11 Marginal Time Available for Crossing vs. D (Both Approaches from Inside)

The radius of curvature was obtained for the major road by staking out a one hundred foot chord along the horizontal curve using wire and chaining pins. The distance from the middle ordinate of this chord to the edge of pavement was then measured as shown in Figure 5-12.

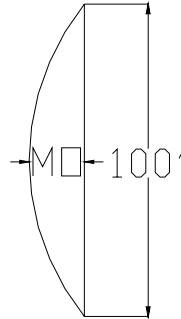


Figure 5-12 Middle Ordinate Approximation of Curve

The length from the middle ordinate to the chord was then used to compute the radius as shown in the equation below:

$$R = \frac{10000}{8 * MO} + \frac{MO}{2},$$

where:

R = radius of curvature (feet),

MO = length of middle ordinate (feet).

For modeling purposes, it was necessary to convert the radius values to degree of curve. The reason for this is that as curve sharpness increases, curve radius decreases with the exception of a tangent section. A tangent section has an infinite radius and such values cannot be used in the modeling process. Degree of curve corrects for this problem because it has a finite value without exception. The radius values were converted to degree of curvature using the equation:

$$D = \frac{5729.6}{R},$$

where:

D = degree of curvature (degrees per 100-ft chord length),

R = radius of curvature (feet).

Table 5-7 Intersections Under Analysis (4-lane Case)

Major Road	Minor Road	MO (in)	R (ft)	D (° per 100 ft)	avg. e (%)
US-41/52	CR 600 W.	3.5	4286	1.3	4.81%
US-41/52	CR 700 N.	3.5	4286	1.3	4.08%
US-52	SR-352 / CR 600 S.	3.0	5000	1.1	0.98%
US-52	CR 600 E.	0.0	0	0.0	0.00%
US-36	CR 571 E. / CR 575 E.	4.0	3750	1.5	4.15%
SR-63	SR-71	3.0	5000	1.1	3.70%
SR-63	Market Street	5.0	3000	1.9	4.92%
SR-63	Barnhart Road	4.0	3750	1.5	2.50%
SR-63	SR-263 North Jct.	0.0	0	0.0	0.00%
SR-63	SR-263 South Jct.	4.0	3750	1.5	5.27%
SR-63	Division Road	4.0	3750	1.5	5.46%
US-31	CR 300 S.	2.0	7500	0.8	4.52%
US-31	9A Road	8.0	1875	3.1	4.18%
US-31	Tyler Road	0.0	0	0.0	0.00%
US-31	Quinn Trail	10.0	1875	3.1	3.63%
US-50	Stoops Road	5.5	2728	2.1	4.79%
US-50	Texas Gas Road	2.0	7500	0.8	4.16%
US-50	SR-262 / Station Hollow	1.0	15000	0.4	2.61%
US-421	Old SR-62	5.0	3000	1.9	6.90%
SR-37	Victor Pike	2.5	6000	1.0	3.96%
SR-37	Burma Road	2.0	7500	0.8	3.57%
SR-67	SR-39 North Jct.	5.0	3000	1.9	5.94%
SR-67	Centerton Road / Rob Hill Road	3.0	5000	1.1	3.24%
US-50/150	CR 300 W.	2.0	7500	0.8	3.53%
US-50/150	SR-257	3.0	5000	1.1	3.25%
US-41	CR 1025 S.	2.0	75000	0.8	3.00%
US-41	CR 150 S.	4.0	3750	1.5	3.36%
US-41	CR 350 N.	4.0	3750	1.5	2.00%
US-41	SR-56	0.0	0	0.0	0.00%
US-41	Old US-41	4.0	3750	1.5	1.00%
US-41	CR 575 N.	1.0	15000	0.4	0.96%
US-41	CR 550 W.	4.5	3334	1.7	4.21%
US-41	SR-241	5.0	3000	1.9	6.44%
US-41	CR 500 W.	3.5	4286	1.3	2.24%
US-41	CR 1000 N.	5.0	3000	1.9	5.33%
US-41	CR 1100 Ne.	2.0	7500	0.8	1.93%
US-41	SR-550	0.0	0	0.0	0.00%
US-50	CR SE 500 E.	0.0	0	0.0	0.00%
US-50	CR SE 900 E.	1.0	15000	0.4	1.76%
SR-37	SR-54/58	5.0	3000	1.9	7.23%
SR-37	CR 475 N.	3.0	3000	1.1	4.10%
US-41	CR 400 S.	4.5	3334	1.7	3.88%
US-41	CR 200 N.	4.0	3750	1.5	6.08%
US-41	CR 575 N.	5.0	3000	1.9	3.17%
US-41	Radio Avenue	2.0	7500	0.8	0.90%
US-41	Campbell Road / Old State Road	4.0	3750	1.5	1.11%
SR-62	Posey County Line Road	3.0	5000	1.1	2.00%
SR-62	McDowell Road	6.0	2500	2.3	5.15%
SR-66	St. Joseph Road	3.0	5000	1.1	3.47%

Superelevation was measured in 12 locations at each intersection. Measurements were taken at the same three locations in each of the four lanes using an electronic level. One measurement was taken directly in the middle of each intersection and another measurement was taken at one hundred feet in each direction along the major road. All measurements

obtained were to the nearest tenth of a percent. Curvature and superelevation information at the studied intersections is shown in Table 5-7.

Other variables collected at each intersection were the posted speed limit on the major road, the presence or absence of flashers, and whether or not the intersection was located on a vertical curve. 47 of the 49 intersections had a posted speed limit of 55 along the major road. The other two intersections had speed limits of 50. Six intersections had flashers and four intersections were located on crest curves. Intersection angle was measured using aerial photographs. For each intersection, a protractor was used to determine the skew (difference from 90°) for each leg of the intersection.

5.4. Crashes

The Indiana State crash database was used to extract the crash records for each of the 49 intersections. These crash records were then used to obtain copies of each individual crash report from microfilm. The crash reports were used to clear up issues that arose when assembling data from the database and to correct mistakes that would have otherwise gone unnoticed. A number of crash reports contained ambiguous location information and had to be removed from the sample. This happens where two routes overlap, forming two different intersections. In Morgan County, near Martinsville, State Route 39 East intersects State Route 67 as shown in Figure 5-13. A few miles north, State Route 39 West intersects State Route 67. The Indiana crash database cannot distinguish between the two intersections because they are coded using the same, so-called, pseudonumbers.

A number of other problems were identified, including cases where the wrong coding was simply entered into the database. It is recommended that for future studies, the original crash reports be obtained where possible to fix such problems.

After examining the complete set of crash reports, the final sample consisted of 258 crashes over the four-year period from 1997-2000. For each crash, the following information was extracted for use in the development of crash frequency and severity models and in the binomial comparison test:

- Severity (fatal, personal injury, property damage only)
- Light condition (daylight, dawn/dusk, dark/street lights on, dark/street lights off, dark/no street lights)
- Weather (clear, cloudy, rain, snow, sleet/hail/freezing rain, fog/smoke/smog)

- Road surface condition (wet, muddy, slush, snow/ice)
- Primary contributing circumstance (Table 5-7).

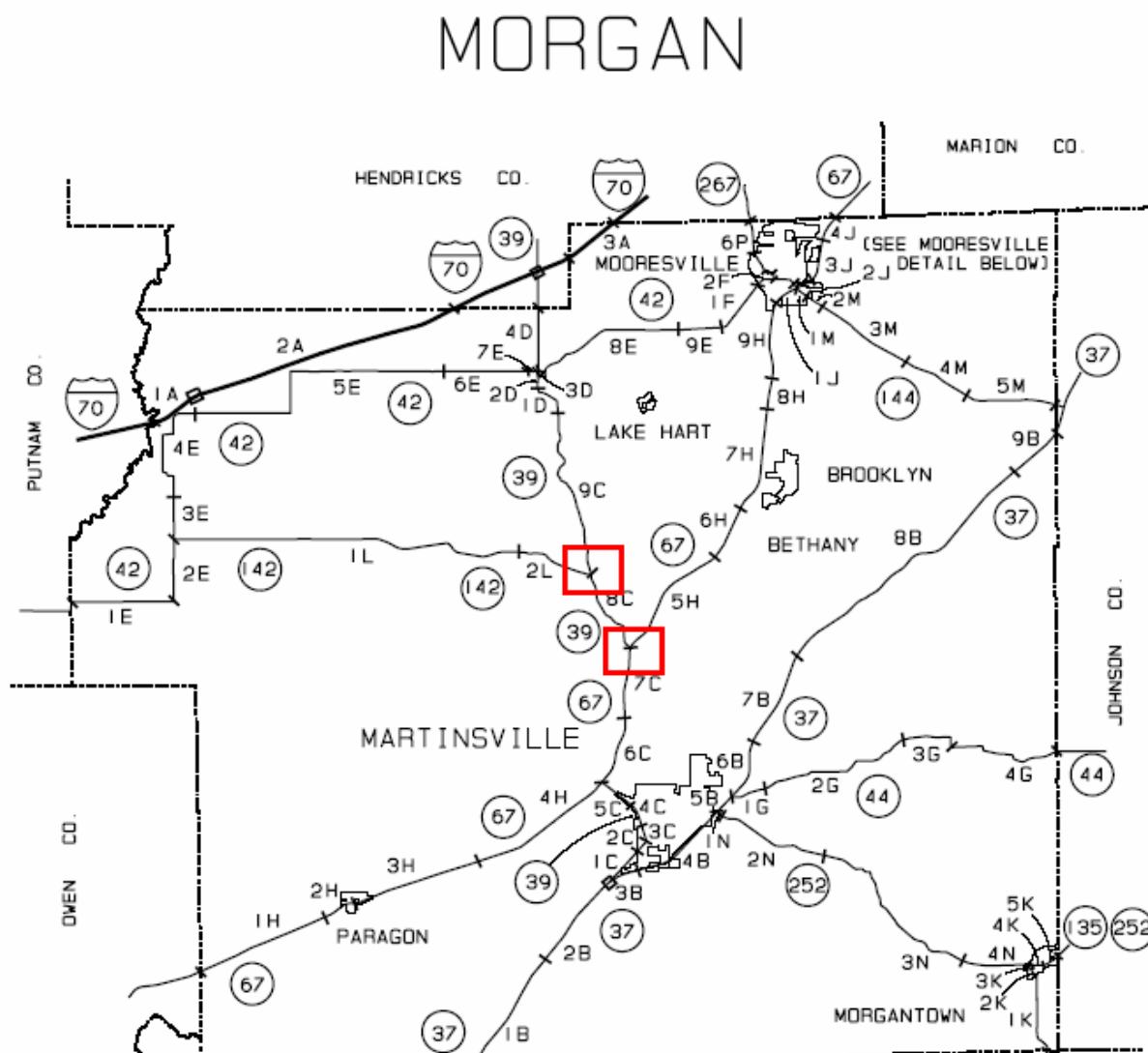


Figure 5-13 SR-67 & SR-39 Examples

Table 5-8 shows the 17 different contributing factors listed on the crash reports for the sample intersections. Over 75% of these crashes were caused by failure to yield and driver inattention. Unfortunately, these are characteristics that are beyond the direct control of the transportation agency as they are dependent on individual drivers. The statistical models in the following chapters attempt to explain why these mistakes were made and what, if anything, can be done to correct them.

Table 5-8 Primary Contributing Circumstances

Primary Contributing Circumstance	Number of Crashes
Failure to Yield Right-of-Way	135
Driver Inattention	60
Other	13
Animal on Roadway	12
Improper Turning	8
Material on Surface	5
Disregard Regulatory Sign	4
Following Too Closely	4
Alcohol	3
Brake Failure	3
Unsafe Speed	2
Left of Center	2
Unknown	2
Drugs	1
Unsafe Backing	1
Tire Failure	1
Windshield Defective	1
View Obstructed by Other	1

5.5. Safety Evaluation

All volume, crash, and geometry data were combined into a single table using Excel. Tables 5-9 and 5-10 show descriptive statistics for all data used in the modeling process. Table 5-9 shows statistics for all continuous variables. Table 5-10 shows statistics for all binary (indicator) variables. Binary variables are set equal to one if the condition is satisfied and zero if the condition is not satisfied.

Table 5-9 Descriptive Statistics for Continuous Variables

Variable	Explanation	Units	Min.	Max.	Mean	Std.Dev.
ADT1	Major Road AADT	veh per day	3570	24260	12572	6036
ADT2	Minor Road AADT	veh per day	34	6126	1026	1216
SPEED	Speed Limit	mph	50	55	54.69	1.20
PLW	Primary Lane Width	ft	11	12	11.85	0.23
SAW	Secondary Approach Width	ft	16	38	22.00	4.43
PSW	Primary Shoulder Width	ft	2	10	5.62	1.59
SSW	Secondary Shoulder Width	ft	0	10	0.89	1.99
D	Degree of Curvature	° per 100-ft chord length	0	3	1.24	0.73
MEDIAN	Median Width	ft	5	250	36.00	38.39
SKEWLEFT	Skew Angle to Left	degrees	0	30	6.78	9.45
SKEWRIGH	Skew Angle to Right	degrees	0	30	4.92	8.69
TAC	Time Available for Crossing	sec	8.60	52.50	16.53	8.76
CT	Crossing Time	sec	3.90	5.20	4.58	0.31
MTAC	TAC-CT	sec	9.30	67.10	22.12	47.48
MINMTAC	1/MTAC	1/sec	0.01	0.11	0.05	0.02

Table 5-10 Descriptive Statistics for Binary Variables

Variable	Explanation	Number of Occurrences	% of Occurrences
SR	State Road	11	22.45%
CREST	Crest	4	8.16%
CHAN	Channelization	6	12.24%
ML	Multi-Lane Minor Approach	4	8.16%
RT	Right-Turn Lane	39	79.59%
LT	Left-Turn Lane	35	71.43%
LEG	3-Leg Intersection	15	30.61%
MED2	Median Able to Store 2 or More Cars	15	30.61%
MED3	Median Able to Store 3 or More Cars	3	6.12%
FLASHER	Flasher	6	12.24%
RAIN	Rain Conditions at Time of Crash	8	3.28%
DARK	Dark Conditions at Time of Crash	76	31.15%

5.5.1. Model Development

Using the obtained traffic volumes, intersection geometry, and crash data, LIMDEP was used to develop a negative binomial model to determine the effects of intersection geometry on crash frequency. The negative binomial model takes the form:

$$C = K \cdot AADT_1^{\alpha_1} \cdot AADT_2^{\alpha_2} \cdot \exp(\beta_1 X_1 + \beta_2 X_2 + \dots + \beta_N X_N), \quad (5.1)$$

where:

C = expected # of crashes

AADT1 = average annual daily traffic on primary road

AADT2 = average annual daily traffic on secondary road

K, α_1 , α_2 , β_1 , β_2 , β_N = constants

X_1 , X_2 , X_N = vectors of explanatory variables.

One of the initial problems in the model development process was incorporating both degree of curvature and superelevation into the model. As the two variables were strongly correlated ($R=0.62$), when both were included in a model, the resulting parameter estimates were inconsistent due to multicollinearity. For this reason, one of the two elements had to be left out of the model. The superelevation data was determined to be less reliable due to issues such as construction. For example, several of the intersections had significantly different superelevation rates between each of the four lanes. As such, degree of curvature was used in the modeling process to determine the full effect of curvature.

An initial model was developed of the form shown in Equation 5-1. Table 5-11 shows the results for the full model with all variables included. The table shows that none of the nineteen variables are statistically significant based on our 10% significance threshold. The model appears to perform rather poorly, with a ρ^2 value of only 0.04. Additionally, there appear to be some problems with some of the parameter estimates. For example, several of the variables have coefficients that are inconsistent with expectations. The results show 3-legged intersections to experience a greater number of crashes than 4-legged intersections. Also, crash frequency is shown to decrease for intersections where the minor road is a state route, rather than a local or county road. These results are counterintuitive and in conflict with past research. A possible explanation for these inconsistencies is the relatively small sample size. As the sample consisted of only 49 intersections, some of these results may be due to pure randomness. Another possibility is that the model has been incorrectly specified.

Traditionally, crash frequency models for intersections are developed using AADT values for each of the intersecting roads as is the case for this initial model. However, this model specification may be incorrect because different types of crashes involve different traffic flow streams. For example, rear-end collisions occurring on the major road are not likely to be seriously affected by the volume of traffic on the minor road. It may be more appropriate to model crashes using crash type-specific exposure terms.

For this reason, a second crash frequency model was formulated using AADT values related specifically to each type of crash. Six different types of crashes were identified based on the traffic flow streams involved:

- Right-angle collisions (RA)
- Rear-end collisions on the major road (RE1)
- Rear-end collisions on the minor road (RE2)
- Single-vehicle crashes on the major road (SV1)
- Single-vehicle crashes on the minor road (SV2)
- Median-opposing crashes (MO)

Table 5-11 Traditional Crash Frequency Model

Variable	Explanation	Coeff.	Std.Err.	t-ratio	P-value
ONE	Constant	-7.1005	23.1232	-0.3071	0.7588
ADT1	Exposure Variable (Major Road Traffic)	0.3536	0.5672	0.6234	0.5330
ADT2	Exposure Variable (Minor Road Traffic)	0.8312	0.5356	1.5519	0.1207
SPEED	Speed Limit	0.2218	0.2486	0.8924	0.3722
SR	State Road Indicator Variable	-0.1595	1.0729	-0.1487	0.8818
CREST	Crest Indicator Variable	0.8120	1.4163	0.5733	0.5664
CHAN	Channelization Indicator Variable	0.7357	0.7383	0.9966	0.3190
PLW	Primary Lane Width	-1.0511	1.3009	-0.8080	0.4191
ML	Multi-Lane Approach Indicator Variable (Minor Road)	-0.7295	1.1430	-0.6383	0.5233
SSW	Secondary Shoulder Width	0.0401	0.1515	0.2647	0.7912
RT	Right-Turn Lane Indicator Variable	-1.4181	1.2512	-1.1334	0.2570
LT	Left-Turn Lane Indicator Variable	1.7420	1.2055	1.4450	0.1485
D	Degree of Curvature	0.2170	0.4130	0.5255	0.5992
LEG	3-Leg Indicator Variable	0.7647	1.0991	0.6958	0.4866
MED2	2-Car Storage Indicator Variable	-0.4647	0.9958	-0.4666	0.6408
MED3	3-Car Storage Indicator Variable	1.2612	1.3594	0.9278	0.3535
FLASHER	Flasher Indicator Variable	0.9552	0.7755	1.2318	0.2180
SKEWLEFT	Skew Angle to Left (From Inside of Curve)	0.0072	0.0368	0.1944	0.8459
SKEWRIGH	Skew Angle to Right (From Inside of Curve)	-0.0218	0.0352	-0.6181	0.5365
MTACINV	Inverse of Marginal Time Available for Crossing	-3.9141	12.8168	-0.3054	0.7601
Alpha	Overdispersion Parameter	0.6539	0.3785	1.7276	0.0841

To search for other patterns in the data, the crashes were subdivided based on the approach(es) the colliding vehicle(s) were traveling on. The four approaches are shown in Figure 5-14. Figure 5-15 shows each of the six crash types in graphical form.

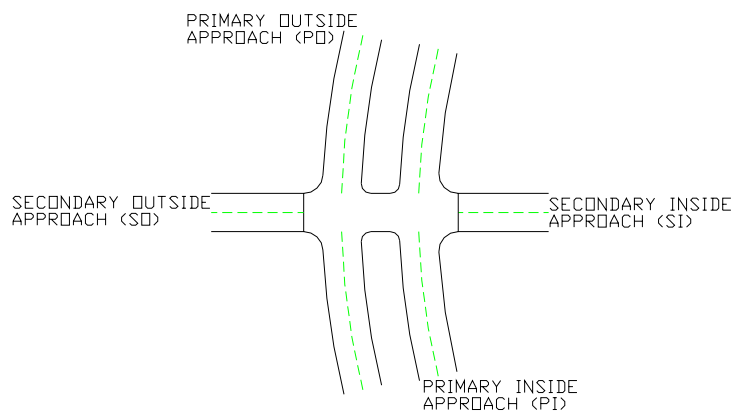


Figure 5-14 Intersection Approaches

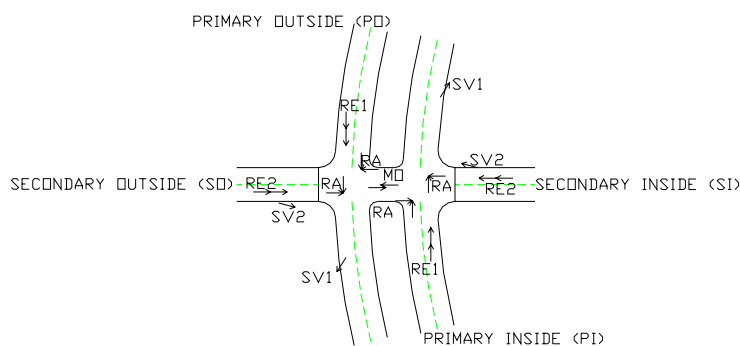


Figure 5-15 Crash Types

The numbers of crashes by type within the intersection sample are shown in Table 5-12. The subtype denotes the approaches on which the vehicles involved in each crash were traveling.

Table 5-12 Number of Crashes by Type

Type	Acronym	Subtype	# of Crashes by Subtype	by Type
Right-Angle	RA	Primary Outside-Secondary Outside	42	188
		Primary Outside-Secondary Inside	104	
		Primary Inside-Secondary Inside	22	
		Primary Inside-Secondary Outside	20	
Single-Vehicle on Major Road	SV1	Primary Outside	15	27
		Primary Inside	12	
Single-Vehicle on Minor Road	SV2	Secondary Outside	2	2
		Secondary Inside	0	
Rear-End on Major Road	RE1	Primary Outside	8	12
		Primary Inside	4	
Rear-End on Minor Road	RE2	Secondary Outside	12	21
		Secondary Inside	9	
Median-Opposing	MO	Secondary Outside-Secondary Inside	8	8

Separate exposure variables were developed for each of the six crash types. Two variables were created for the right-angle crash type and one variable for each of the five remaining crash types. The right-angle type has two exposure terms because two flow streams are involved in such crashes. For the other crash types, involved vehicles were traveling within a single flow stream, meaning only one exposure term was necessary. In order to apply the correct exposure term to each crash type, six binary indicator (dummy) variables were created, one for each crash type. These variables are:

- RA for right-angle collisions

- SV1 for single-vehicle collisions on the major road
- SV2 for single-vehicle collisions on the minor road
- RE1 for rear-end collisions on the major road
- RE2 for rear-end collisions on the minor road
- MO for median-opposing collisions

These variables were set to one for the particular zone of interest and zero for all other zones. For example, for the case of right-angle collisions, the right-angle indicator variable (RA) is set to equal one and the remaining variables are all set to zero. These variables were then combined with volume to create interaction terms representing the AADT variables for each crash type.

The right-angle volume variables are ADT1RA and ADT2RA. ADT1RA was obtained by dividing the major road AADT by two and multiplying by the right-angle indicator variable ($RA * ADT1/2$). ADT2RA was obtained in the same manner, except instead using the minor road AADT ($RA * ADT2/2$).

It was assumed that single vehicle crashes involved only the flow stream in which the crash occurred. The corresponding volume variable, ADT1SV, was set to equal half of the major road AADT times the single-vehicle indicator variable for the major road ($SV1 * ADT1/2$). A similar approach was used in determining ADT2SV, which is equal to half of the minor road AADT multiplied by the single-vehicle indicator variable for the minor road ($SV2 * ADT2/2$).

As with the single-vehicle crashes, it was assumed that rear-end crashes involved only the flow stream in which the crash occurred. The volume variables were treated the same way, with ADT1RE being set equal to half of the major road AADT times the rear-end indicator variable for the major road ($RE1 * ADT1/2$) and with ADT2RE being set equal to half of the minor road AADT times the rear-end indicator variable for the minor road ($RE2 * ADT2/2$).

The median-opposing crashes are composed of sideswipe collisions between the two minor flow streams. For these crashes, the best fit for the regression resulted from summing the traffic volumes from each approach. For modeling purposes, the variable ADTMO is equal to the sum of the AADT for each minor approach, which is simply the total minor road AADT times the median-opposing indicator variable ($MO * ADT2$). The traffic variables are all summarized in Table 5-13.

Using these traffic volumes and geometric characteristics, a type-specific crash frequency model was developed to determine the effects of each variable on intersection safety.

The model was constructed with crash type-specific exposure functions as previously explained. The remaining intersection geometry variables took common values across the six crash types. The parameter estimates for these geometry variables give the average effect across all crash types for each variable. The resulting model can be used to predict the expected number of crashes by type or the expected number of crashes for all types.

Table 5-13 Exposure Variables

Variable Name	Value	Explanation of Indicator Variables
ADT1RA	= (ADT1/2) * RA	RA = right-angle collision type
ADT2RA	= (ADT2/2) * RA	RA = right-angle collision type
ADT1SV	= (ADT1/2) * SV1	SV1 = single-vehicle collision type (major road)
ADT2SV	= (ADT2/2) * SV2	SV2 = single-vehicle collision type (minor road)
ADT1RE	= (ADT1/2) * RE1	RE1 = rear-end collision type (major road)
ADT2RE	= (ADT2/2) * RE2	RE2 = rear-end collision type (minor road)
ADTMO	= (ADT2) * MO	MO = median-opposing collision type

Note: ADT1=AADT for major road, ADT2=AADT for minor road

Results for the full model (with all variables included) are presented in Table 5-14. The same results for the reduced model (statistically insignificant variables removed) are shown in Table 5-15. As variables are removed from the model, their effects are captured by those variables that remain in the model. Thus, the full model is used to determine the effects of each variable and the reduced model is more appropriate for accident prediction purposes.

The results show this model to be superior to the previously developed model of the traditional form. While the traditional model had a ρ^2 value of 0.14, the type-specific model had an improved ρ^2 value of 0.23. Additionally, the parameter estimates for the type-specific model are consistent with expectations, which was not the case for the traditional model. Additionally, the overdispersion parameter is significantly less for the type-specific model, indicating more of the variation is being explained by the geometry variables.

Note that this model does not predict the frequency of all crashes but the frequency of specific types of crashes. To find the predicted frequency of all crashes, the results from the six type-specific models must be added together. The six crash type models are shown in Equations 5-2 through 5-7.

- Right-Angle Crashes

$$C = \left(\frac{ADT1}{2}\right)^{0.31} \left(\frac{ADT2}{2}\right)^{0.39} \cdot \exp(0.23SPEED + 1.50CHAN + 1.10LT + 0.27D + 0.76MED3 + 0.87FLASH - 1.13RT - 17.4) \quad (5.2)$$

- Single-Vehicle Crashes on the Major Road

$$C = \left(\frac{ADT1}{2}\right)^{0.42} \cdot \exp(0.23SPEED + 1.50CHAN + 1.10LT + 0.27D + 0.76MED3 + 0.87FLASH - 1.13RT - 17.4) \quad (5.3)$$

- Single-Vehicle Crashes on the Minor Road

$$C = \exp(0.23SPEED + 1.50CHAN + 1.10LT + 0.27D + 0.76MED3 + 0.87FLASH - 1.13RT - 17.4) \quad (5.4)$$

- Rear-End Crashes on the Major Road

$$C = \left(\frac{ADT1}{2}\right)^{0.33} \cdot \exp(0.23SPEED + 1.50CHAN + 1.10LT + 0.27D + 0.76MED3 + 0.87FLASH - 1.13RT - 17.4) \quad (5.5)$$

- Rear-End Crashes on the Minor Road

$$C = \left(\frac{ADT2}{2}\right)^{1.28} \cdot \exp(0.23SPEED + 1.50CHAN + 1.10LT + 0.27D + 0.76MED3 + 0.87FLASH - 1.13RT - 22.1) \quad (5.6)$$

- Median-Opposing Crashes

$$C = (ADT2)^{1.28} \cdot \exp(0.23SPEED + 1.50CHAN + 1.10LT + 0.27D + 0.76MED3 + 0.87FLASH - 1.13RT - 17.4) \quad (5.7)$$

The model form for predicting the total number of crashes is shown in Equation 5.8.

$$C = \left[\left(\frac{ADT1}{2} \right)^{0.31} \cdot \left(\frac{ADT2}{2} \right)^{0.39} + \left(\frac{ADT1}{2} \right)^{0.42} + \left(\frac{ADT1}{2} \right)^{0.33} + 0.00874 \left(\frac{ADT2}{2} \right)^{1.28} + (ADT2)^{0.36} + 1 \right] \cdot \exp(0.23SPEED + 1.5CHAN + 1.1LT + 0.27D + 0.76MEDB + 0.87FLASH - 1.13RT - 17.4) \quad (5.8)$$

Table 5-14 Full Model for Accidents by Type

Negative Binomial Regression				
Maximum Likelihood Estimates				
Dependent variable				CRASH
Weighting variable				ONE
Number of observations				294
Log likelihood function				-236.1843
Restricted log likelihood				-305.5372
Chi-squared				29.7514
Significance level				0.0000
Variable	Explanation	Coeff.	Std.Err.	P-value
ONE	Constant	-10.984	8.5247	0.1976
ADT1RA	RA Exposure Variable (Major Road)	0.3506	0.4009	0.3818
ADT2RA	RA Exposure Variable (Minor Road)	0.6734	0.2242	0.0027
ADT1SV	SV1 Exposure Variable (Major Road)	1.0228	0.5813	0.0785
ADT2SV	SV2 Exposure Variable (Minor Road)	0.3555	2.3812	0.8813
ADT1RE	RE1 Exposure Variable (Major Road)	0.7275	0.8171	0.3733
ADT2RE	RE2 Exposure Variable (Minor Road)	1.3799	0.558	0.0134
ADTMO	MO Exposure Variable (Minor Road)	0.5123	0.3385	0.1302
SPEED	Speed Limit	0.5702	0.8514	0.503
SR	State Road Indicator Variable	0.5061	0.5534	0.3605
CREST	Crest Indicator Variable	1.0398	0.4893	0.0336
CHAN	Channelization Indicator Variable	0.1995	0.5928	0.7364
PLW	Primary Lane Width (ft)	0.341	0.7352	0.6428
ML	Multi-Lane Approach Indicator Variable (Minor Road)	-0.2476	0.4497	0.5819
PSW	Primary Shoulder Width (ft)	-0.1154	0.1125	0.305
SSW	Secondary Shoulder Width (ft)	0.0386	0.0936	0.6801
RT	Right-Turn Lane Indicator Variable	-0.8233	0.5896	0.1626
LT	Left-Turn Lane Indicator Variable	1.0845	0.4975	0.0293
D	Degree of Curvature (degrees per 100-ft chord)	0.3918	0.2532	0.1218
LEG	3-Leg Indicator Variable	0.443	0.5028	0.3783
MED2	2-Car Storage Indicator Variable	-0.2385	0.5283	0.6517
MED3	3-Car Storage Indicator Variable	1.3634	0.7496	0.0689
FLASHER	Flasher Indicator Variable	0.51	0.5402	0.3451
SKEWLEFT	Skew Angle to Left (from Inside of Curve)	0.0049	0.0195	0.802
SKEWRIGH	Skew Angle to Right (from Inside of Curve)	-0.0117	0.0212	0.582
MTACINV	Inverse of Marginal Time Available for Crossing (sec ⁻¹)	-4.2725	6.4409	0.5071
SV1	Single-Vehicle Crash Type (Major Road)	-3.5627	5.862	0.5433
SV2	Single-Vehicle Crash Type (Minor Road)	0.6741	14.947	0.964
RE1	Rear-End Crash Type (Major Road)	-1.8538	8.4848	0.827
RE2	Rear-End Crash Type (Minor Road)	-3.7317	5.3589	0.4862
MO	Median-Opposing Crash Type	0.6462	4.5724	0.8876
Alpha	Overdispersion Parameter	0.4228	0.2063	0.0404

Table 5-15 Reduced Model for Accidents by Type

Negative Binomial Regression				
Maximum Likelihood Estimates				
Dependent variable				CRASH
Weighting variable				ONE
Number of observations				294
Log likelihood function				-230.7697
Restricted log likelihood				-268.5237
Chi-squared				14.8376
Significance level				0.0001
Variable	Explanation	Coeff.	Std.Err.	P-value
ONE	Constant	-17.3787	7.4029	0.0189
ADT1RA	RA Exposure Variable (Major Road)	0.3135	0.1068	0.0033
ADT2RA	RA Exposure Variable (Minor Road)	0.3862	0.1234	0.0017
ADT1SV	SV1 Exposure Variable (Major Road)	0.4232	0.0802	0.0000
ADT1RE	RE1 Exposure Variable (Major Road)	0.3279	0.0834	0.0001
ADT2RE	RE2 Exposure Variable (Minor Road)	1.2824	0.4291	0.0028
ADTMO	MO Exposure Variable (Minor Road)	0.3646	0.1074	0.0007
SPEED	Speed Limit	0.2295	0.1344	0.0875
CHAN	Channelization Indicator Variable	1.4984	0.3622	0.0000
RT	Right-Turn Lane Indicator Variable	-1.1315	0.3481	0.0012
LT	Left-Turn Lane Indicator Variable	1.1027	0.2259	0.0000
D	Degree of Curvature (degrees per 100-ft chord)	0.2684	0.1329	0.0434
MED3	3-Car Storage Indicator Variable	0.7575	0.4126	0.0664
FLASHER	Flasher Indicator Variable	0.8714	0.2441	0.0004
RE2	Rear-End Crash Type (Minor Road)	-4.7404	3.0797	0.1237
Alpha	Overdispersion Parameter	0.3260	0.1499	0.0297

5.5.1.1. Model Sensitivity

The full model provides the most accurate estimate of the true value for each parameter in the model. Using the full model, the sensitivity of each variable was calculated to determine the practical significance of each variable. Table 5-16 shows the sensitivity of each variable in the full model. The sensitivity is the effect on crash frequency that occurs as a result of increasing an individual variable from its minimum to maximum value with all other variables held constant as illustrated in Equation 5.9.

$$Sensitivity = \frac{C(X_{max}, Y_{mean}) - C(X_{min}, Y_{mean})}{C(X_{mean}, Y_{mean})}, \quad (5.9)$$

where X is the parameter of interest and Y is the set of all remaining parameters.

If the sensitivity value for a variable is equal to zero, the variable has no effect in the model. If the sensitivity is greater than one, then crash frequency tends to increase as the variable is increased. Conversely, if the sensitivity value is negative, then crash frequency tends to decrease as the variable is increased.

As expected, traffic volume plays a significant role in crash occurrence. Crash frequency increases significantly as volume is increased on each road, particularly for the minor road. ADT1 has a sensitivity of 1.86 and ADT2 has a sensitivity of 7.79, indicating the minor road ADT has a more significant effect on crash frequency than the major road ADT.

As expected, crashes tended to increase with degree of curvature. As degree of curvature is increased from zero (a tangent intersection) to the maximum value in the sample of 3.1, an increase in crashes of approximately 327% can be expected. Based upon this result, design standards for curvature may be developed by INDOT for operating speeds in the range of 55 mph. Further details are provided in

Chapter 7 of this report.

The SR indicator variable shows crashes to be more frequent on state roads with all other variables taken to be equal. This could mean that drivers on state roads tend to take more risks when driving or the result could be influenced by the higher speeds along state roads.

Channelization is also associated with a higher number of crashes. However, this may be due to the fact that channelization is typically used when high volumes of traffic are entering the major road from the minor road. In actuality, the channelization itself is not the cause of the increase in crashes.

Similarly, intersections where flashers are installed tend to have a higher number of crashes. This result does not imply that the flashers are making these locations more hazardous. Flashers were likely installed at the locations due to recurring crash problems.

Crashes also increase as intersections are skewed to the left from the inside of the curve. This may be picking up on some visibility problems as drivers must turn further to their right to view oncoming traffic.

Sight restriction is also a possible cause of the increase in crashes associated with left-turn lanes. The view of oncoming traffic from the median may be obstructed by vehicles in the auxiliary lane.

Conversely, right-turn lanes tend to significantly decrease the number of crashes occurring at an intersection. When no right-turn lanes are present, several problems are possible. Stopped vehicles may not know whether oncoming traffic will turn or continue past the intersection. Additionally, traffic behind right-turning vehicles may be surprised by sudden deceleration prior to exiting the major road.

Table 5-16 Model Sensitivity

Variable	Min.	Mean	Max.	Sensitivity
ADT2	17	513	3063	7.79
CHAN	0	0.02	1	2.28
ADT1	1785	6286	12130	1.86
FLASHER	0	0.12	1	1.68
MED3	0	0.06	1	1.37
D	0	1.23	3.1	1.29
SR	0	0.22	1	1.04
LT	0	0.71	1	0.95
PLW	11	11.85	12	0.77
SKEWLEFT	0	6.78	30	0.58
SPEED	50	54.69	55	0.57
ML	0	0.08	1	0.25
MINMTAC	0.01	0.05	0.11	-0.01
CREST	0	0.08	1	-0.19
SKEWRIGH	0	4.92	30	-0.29
MED2	0	0.31	1	-0.31
LEG	0	0.31	1	-0.36
SSW	0	0.89	10	-0.85
RT	0	0.8	1	-2.06

The model shows crashes to decrease as median width is increased. However, excessively wide medians show an increase in crash frequency. This fact may be due to randomness because of the relatively small sample size. Only three intersections in the sample had medians capable of storing three or more cars and one of these intersections had the most crashes in the sample.

The remaining variables displayed little practical or statistical significance. It does not appear that sight distance, vertical curvature, and lane width have a significant impact on crash frequency.

5.6. Binomial Comparison of Proportions

A number of variables could not be included in the crash frequency and severity models because they experience change over time. Such variables include lighting, weather, and pavement conditions. However, such effects can be analyzed by comparing two similar samples, one with intersections located on curves and the other with intersections located on tangents.

The first sample consisted of all 244 crashes from the 43 intersections located on curves used in the four-lane analysis. The second sample consisted of all 1,378 crashes occurring at 471 tangent intersections along the same divided four-lane highways. The intersections in the second sample were selected using the Indiana crash database. Each intersection in the sample was checked to make sure it was two-way stop controlled and not signalized.

The crash-specific information for each of the aforementioned variables can be obtained from the Indiana crash database. By comparing the proportion of crashes related to each variable between the two samples, it can be determined if a variable is overrepresented or underrepresented for the intersections on curves. The appropriate statistical test is performed using the binomial distribution. Our best estimate of the true proportion of crashes occurring at intersections on curves, or likelihood of success in the binomial meaning, is:

$$s = \frac{C}{C + T},$$

where

C = the total number of crashes at intersections located on curves

T = the total number of crashes at intersections located on tangents.

Using this estimate of the true proportion, we can check if the number of crashes on curves, C_k of a particular category k (night, right-angle, injuries, etc.) is underrepresented or overrepresented in the number of crashes at significance level f . This is done by calculating the binomial likelihood, $P(X \leq C_k)$, given the number of trials, $(C_k + T_k)$, likelihood of success, $s_k = s$, and the number of successes, C_k . If the likelihood is smaller than f , then the category k is underrepresented, implying that the true likelihood of success s_k is lower than s . Similarly, if the likelihood is larger than $1-f$, then the category is overrepresented. A threshold f -value of 0.10 was used for this analysis.

5.6.1. Crash Type

A comparison was made between the proportions of crashes by type between the two samples in an attempt to identify differences in crash patterns between intersections located on tangent and curved highway sections. Table 5-17 shows right-angle and single-vehicle crashes to be overrepresented in the superelevated sample and rear-end and sideswipe collisions to be underrepresented. The increased difficulty of maneuvering on curves may be an explanation for this result. Drivers may have trouble negotiating curves or avoiding potential hazards, such as crossing vehicles. There is no clear explanation as to why the rear-end and sideswipe crashes are underrepresented.

Table 5-17 Crashes by Type

Crash Type	Number of Crashes		Proportion	Likelihood	Conclusion
	Tangent	Curve	on Curve		
Right-Angle	757	180	19.21%	1.000	Overrepresented
Rear-End	402	30	6.94%	0.000	Underrepresented
Sideswipe	120	8	6.25%	0.002	Underrepresented
Single-Vehicle	99	26	20.80%	0.969	Overrepresented
Total	1378	244	15.04%		

5.6.2. Lighting Conditions

The lighting conditions at the time of each crash were available from field E39 of the Indiana crash database. Using this information, the proportion of dark crashes was compared between the two samples to determine whether the combination of curvature and darkness had an effect on crash frequency. Results are shown in Table 5-18.

The combination of curvature and darkness appears to make intersections particularly susceptible to crashes. This is particularly true for right-angle crashes, which were the only of the four crash types to be overrepresented. Single-vehicle crashes were very close, missing the significance threshold by only 0.002.

Table 5-18 Crashes Occurring Under Dark Conditions

Crash Type	Number of Crashes		Proportion	Likelihood	Conclusion
	Tangent	Curve	on Curve		
Right-Angle	154	55	26.32%	1.000	Overrepresented
Rear-End	65	9	12.16%	0.308	Uncertain
Sideswipe	27	3	10.00%	0.319	Uncertain
Single-Vehicle	34	9	20.93%	0.898	Uncertain
Total	280	76	21.35%	0.999	Overrepresented

In the case of right-angle collisions, it is possible that the intersections located on curves are not illuminated well enough by headlights for drivers to be able to spot each other. Consequently, vehicles may attempt crossing the major road without a sufficient gap between vehicles. Also, drivers traveling along the major road may not be able to see the vehicles entering from the minor road, causing a similar situation. In the single-vehicle case, drivers may simply not be able to properly read the curve as they are approaching the intersection. Lack of sufficient lighting is again a likely cause of this problem. It is recommended that the option of lighting installation be explored whenever an intersection is being considered for design on a superelevated curve.

5.6.3. Weather Conditions

The weather conditions for each crash were available from field E40 of the crash database. The crashes were separated into three groups based on the weather at the time of the crash: clear, rain, and snow. The proportion of crashes occurring during rain and snow were then compared between the two samples to determine whether the combination of curvature and adverse weather conditions led to a change in crash frequency. Results are shown in Tables 5-19 and 5-20.

Table 5-19 Crashes Occurring Under Rain Conditions

Crash Type	Number of Crashes		Proportion	Likelihood	Conclusion
	Tangent	Curve	on Curve		
Right-Angle	71	7	8.97%	0.084	Underrepresented
Rear-End	55	1	1.79%	0.001	Underrepresented
Sideswipe	13	0	0.00%	0.120	Uncertain
Single-Vehicle	16	0	0.00%	0.074	Underrepresented
Total	155	8	4.91%	0.000	Underrepresented

For both rain and snow conditions, the intersections on curves are shown to be underrepresented. While 12.6% of crashes on tangents occurred during rain events, only 3.3% of crashes on curves occurred under these conditions. Similarly, 4.7% of crashes on tangents occurred during snow events and only 1.2% of crashes on curves occurred during snow events.

In both cases, the results of the comparison of proportions are counterintuitive. One would expect the number of crashes on curves to be overrepresented in each case, but the opposite is true. This result is possibly due to changes in driver behavior under adverse weather conditions. As weather conditions worsen, drivers may begin to drive more cautiously than under normal weather conditions. When traveling along curves, drivers may tend to drive more slowly if

the roads are wet or icy. Such results do not translate into the intersection itself being safer. It is more likely indicating that drivers perceive the intersection as less safe and, consequently, they are driving more cautiously.

Table 5-20 Crashes Occurring Under Snow Conditions

Crash Type	Number of Crashes		Proportion	Likelihood	Conclusion
	Tangent	Curve	on Curve		
Right-Angle	25	1	3.85%	0.081	Underrepresented
Rear-End	16	0	0.00%	0.074	Underrepresented
Sideswipe	5	0	0.00%	0.443	Uncertain
Single-Vehicle	18	2	10.00%	0.403	Uncertain
Total	64	3	4.48%	0.006	Underrepresented

5.6.4. Pavement Conditions

The pavement conditions for each crash were available from field E43 of the crash database. Using this data, the crashes in the sample were separated into three groups based on the surface conditions at the time of the crash: clear, wet, and icy. The proportion of crashes occurring under wet and icy pavement conditions was then compared between the two samples to determine if the combination of curvature and poor pavement conditions has a noticeable effect on crash frequency. Results are shown in Tables 5-21 and 5-22. As expected, the proportion of crashes under wet and icy pavement conditions is very strongly correlated to the proportion of crashes under rain and snow conditions, respectively.

The results of this comparison provide mixed results. For icy pavements, there does not appear to be a clear relationship between the tangent and curve sections. For the case of wet pavements, the intersections located on curves are again underrepresented in terms of the total number of crashes. However, for right-angle crashes, the curve sample is actually overrepresented. Based on these results, it is difficult to determine the exact effects of adverse pavement conditions.

Table 5-21 Crashes Occurring on Wet Pavement

Crash Type	Number of Crashes		Proportion	Likelihood	Conclusion
	Tangent	Curve	on Curve		
Right-Angle	109	25	18.66%	0.899	Uncertain
Rear-End	86	1	1.15%	0.000	Underrepresented
Sideswipe	23	1	4.17%	0.105	Uncertain
Single-Vehicle	20	2	9.09%	0.336	Uncertain
Total	238	29	10.86%	0.030	Underrepresented

Table 5-22 Crashes Occurring on Icy Pavement

Crash Type	Number of Crashes		Proportion	Likelihood	Conclusion
	Tangent	Curve	on Curve		
Right-Angle	30	5	14.29%	0.566	Uncertain
Rear-End	18	2	10.00%	0.403	Uncertain
Sideswipe	8	0	0.00%	0.271	Uncertain
Single-Vehicle	27	4	12.90%	0.491	Uncertain
Total	83	11	11.70%	0.227	Uncertain

5.6.5. Crash Severity

The proportion of severe accidents was also compared between the two samples. A severe accident was defined as any crash resulting in an injury or fatality. This information was obtained from field E10 of the crash database. Table 5-23 shows the proportions for each case.

Table 5-23 Crash Severity

Crash Type	Number of Crashes		Proportion	Likelihood	Conclusion
	Tangent	Curve	on Curve		
Right-Angle	390	90	18.75%	0.989	Overrepresented
Rear-End	128	11	7.91%	0.009	Underrepresented
Sideswipe	16	4	20.00%	0.828	Uncertain
Single-Vehicle	23	8	25.81%	0.965	Overrepresented
Total	557	113	16.87%	0.914	Overrepresented

The results show intersections on curves to have a greater proportion of severe injuries than tangent intersections, particularly for right-angle and single-vehicle crashes. This finding served as motivation for the development of the multinomial logit (MNL) models to determine what characteristics are causing crashes at intersections on curves to be more severe.

5.7. Crash Severity Model

For crash severity analysis, a multinomial logit (MNL) model was developed to isolate factors which cause accidents to be more or less severe when they occur. The magnitudes of the factors in the model were examined to determine where improvements to the existing design process were possible.

The objective of the MNL model is to estimate a function that determines the probability of a severe (injury or fatality) outcome. The probability of a crash resulting in an injury or fatality is given by the following equation:

$$P(I/F) = \frac{e^{S_{I/F}}}{1 + e^{S_{I/F}}},$$

where $S_{I/F}$ is the severity function specified through the modeling process, stated mathematically as:

$$S_{I/F} = \beta_{I/F} X_n + \varepsilon_{I/Fn}.$$

The severity function is presented in its full form (with all variables included) in Table 5-24 and the reduced model (with only statistically significant variables included) is presented in Table 5-25. As was the case with the frequency models, the full model provides the most accurate estimate of the true value for each parameter in the model. As variables are removed from the model, their effects are captured by those variables that remain in the model. As such, the “true” effects of each variable are ascertained through use of the full model.

The reduced model serves best as a predictive model as it is simpler and requires less intensive data than the full model. The utility function for the reduced model is:

$$S_{I/F} = 0.68SR + 1.50CHAN + 0.22CT + 1.56RE1 + 2.44RAIN - 0.92RE2 - 0.97LEG - 0.80MED3 - 0.71FLASHER - 0.87$$

5.7.1.1. Model Sensitivity

Table 5-26 shows the sensitivity of each variable in the full model. The sensitivity is the change in the probability of a crash resulting in an injury or fatality that occurs as a result of increasing an individual variable from its minimum to maximum value with all other variables held constant as illustrated in the following equation:

$$Sensitivity = \frac{P_{I/F}(X_{max}, Y_{mean}) - P_{I/F}(X_{min}, Y_{mean})}{P_{I/F}(X_{mean}, Y_{mean})},$$

where X is the parameter of interest and Y is the set of all remaining parameters.

The results show crashes occurring on the major road are more likely to be severe than crashes occurring on the minor road for all crash zones. This is likely due to the higher speed of

vehicles on the major road. Collisions on the minor road tend to be low-speed rear-end collisions. Conversely, collisions on the major road tend to be predominantly high-speed right-angle collisions. These types of collisions are prone to be more severe.

Table 5-24 Full Logit Model for Accident Severity

Multinomial Logit Model					
Maximum Likelihood Estimates					
Dependent variable					SEVERITY
Weighting variable					ONE
Number of observations					258
Log likelihood function					-155.761
Restricted log likelihood					-178.056
Chi-squared					44.5901
Degrees of freedom					24
Significance level					6.51E-03
Variable	Explanation	Coeff.	Std.Err.	t-ratio	P-value
ONE	Constant	-27.8084	20.7618	-1.3394	0.1804
SR	State Road Indicator Variable	1.3714	0.8143	1.6841	0.0922
SPEED	Speed Limit	0.1748	0.2131	0.8204	0.4120
CREST	Crest Indicator Variable	-1.3517	0.9723	-1.3902	0.1645
CHAN	Channelization Indicator Variable	1.7858	0.7716	2.3144	0.0206
PLW	Primary Lane Width	1.2253	1.1310	1.0834	0.2787
SAW	Secondary Approach Width	-0.0222	0.0305	-0.7261	0.4678
PSW	Primary Shoulder Width	-0.2113	0.1799	-1.1743	0.2403
SSW	Secondary Shoulder Width	0.0549	0.0955	0.5747	0.5655
RT	Right-Turn Lane Indicator Variable	-0.2747	0.4738	-0.5798	0.5621
LT	Left-Turn Lane Indicator Variable	-0.8439	0.7793	-1.0829	0.2789
D	Degree of Curvature	-0.0519	0.1120	-0.4638	0.6428
LEG	3-Leg Indicator Variable	-1.5739	0.9441	-1.6670	0.0955
ML	Multi-Lane Approach Indicator Variable (Minor Road)	0.5939	0.4959	1.1977	0.2310
MED2	2-Car Storage Indicator Variable	-0.3738	0.6576	-0.5684	0.5698
MED3	3-Car Storage Indicator Variable	-0.7156	0.6373	-1.1227	0.2616
FLASHER	Flasher Indicator Variable	-1.1701	0.6397	-1.8293	0.0674
TAC	Time Available for Crossing	-0.0178	0.0171	-1.0452	0.2959
CT	Crossing Time	1.5649	0.8350	1.8741	0.0609
SV1	Single-Vehicle Crash Type (Major Road)	5.9748	3.9350	1.5184	0.1289
RE1	Rear-End Crash Type (Major Road)	7.6688	4.0090	1.9129	0.0558
RE2	Rear-End Crash Type (Minor Road)	-1.1909	0.6362	-1.8717	0.0612
MO	Median-Opposing Crash Type	0.0163	0.7805	0.0209	0.9833
DARK	Darkness Indicator Variable	-0.0174	0.8476	-0.0205	0.9836
RAIN	Rain Indicator Variable	2.3210	1.1249	2.0634	0.0391

The state road indicator variable is significant, indicating a tendency for crashes at state-state intersections on curves to be more severe than at state-local intersections. This may be due to the state roads having higher speed approaches.

As crossing time is increased, accidents tend to be more severe. Greater crossing time means vehicles are exposed for a longer time to approaching traffic. If shorter crossing times are required, drivers are more easily able to avoid direct collisions.

Crashes at three-legged intersections tended to be less severe in the sample. Drivers may be able to minimize the severity of an accident because they have more time to react. There are less conflict points to be concerned with at three-legged intersections.

Crashes at intersections where flashing beacons are installed tend to be less severe. This result is intuitive and is likely an indication that drivers are more cautious when they notice a flasher. Reduced speeds are a possible explanation for the decreasing severity.

Table 5-25 Reduced Logit Model for Accident Severity

Multinomial Logit Model				
Maximum Likelihood Estimates				
Dependent variable	SEVERITY			
Weighting variable	ONE			
Number of observations	258			
Iterations completed	5			
Log likelihood function	-161.0416			
Restricted log likelihood	-178.056			
Chi-squared	34.02885			
Degrees of freedom	9			
Significance level	8.83E-05			
	Coeff.	Std.Err.	t-ratio	P-value
ONE	-0.8745	0.4568	-1.9146	0.0555
SR	0.6791	0.3962	1.7142	0.0865
CHAN	1.4981	0.7106	2.1084	0.0350
LEG	-0.9673	0.5291	-1.8283	0.0675
MED3	-0.7966	0.3663	-2.1748	0.0296
FLASHER	-0.7067	0.3750	-1.8844	0.0595
CT	0.2251	0.1063	2.1180	0.0342
RE1	1.5633	0.7576	2.0635	0.0391
RE2	-0.9218	0.5370	-1.7163	0.0861
RAIN	2.4362	1.1132	2.1885	0.0286

Table 5-26 Model Sensitivity

Variable	Min	Mean	Max	Sensitivity
SV1	0	0.10	1	0.56
RE1	0	0.05	1	0.54
RAIN	0	0.03	1	0.46
CT	3.9	4.55	5.4	0.33
CHAN	0	0.06	1	0.31
SR	0	0.28	1	0.30
PLW	11.25	11.92	12	0.28
SPEED	50	54.88	55	0.27
ML	0	0.17	1	0.14
SSW	0	1.57	10	0.13
DARK	0	0.03	1	0.00
D	0	1.46	3.1	-0.04
RT	0	0.77	1	-0.07
MED2	0	0.75	1	-0.09
MED3	0	0.21	1	-0.19
LT	0	0.88	1	-0.21
RE2	0	0.08	1	-0.30
MO	0	0.03	1	-0.33
SAW	0	22.66	50	-0.37
FLASHER	0	0.33	1	-0.37

CHAPTER 6. RIGHT-ANGLE COLLISION CASE

Of the 244 crashes occurring at the studied intersections on curves, 104 were right-angle collisions involving vehicles attempting to cross from the median to the minor leg located on the outside of the curve.

The intersection of US-31 and SR-14, shown in Figure 6-1, experienced 87 right-angle crashes over the seven-year period prior to its median treatment in 1992. Of these 87 crashes, 51 involved vehicles attempting to cross from the median to the outside of the curve.



Figure 6-1 US-31 and SR-14 Intersection (Source: <http://www.mapquest.com>)

In the four-lane study, the intersection of SR-67 and Centerton Road/Rob Hill Road experienced the highest number of crashes. Of the 46 crashes occurring at this intersection between 1997 and 2000, 40 involved the Primary Outside and Secondary Inside flow streams. The intersection, located near Centerton, Indiana, is shown in Figure 6-2.

There is an overrepresentation of this crash type among the sample intersections located on curves. To explain this phenomenon, an attempt was made to develop crash models as in the previous chapter. However, due to the limited sample size and multicollinearity within the data, a suitable model could not be developed.



Figure 6-2 SR-67 & Centerton Road/Rob Hill Road (Source: <http://www.mapquest.com>)

However, some insight was gained from examining the time available for crossing from the inside approach to the outside approach. Table 6-1 shows the marginal time available (MTAC) for crossing at each of the 30 4-legged intersections within the sample. The MTAC is obtained by subtracting the crossing time for the entire intersection from the time available to cross from stop bar of the inside minor approach. Although the results are not statistically significant, there is a trend for intersections with lower MTAC values to experience more crashes. Further exploration of this particular crash zone may prove to be useful in future research.

Another common characteristic of the two aforementioned intersections is that they both have significant skew angles to the left as the driver is passing from the median to the outside leg of the minor road. Although skew angle was not found to be significant in any of the models developed, there is evidence that severely skewed intersections have a tendency to experience an increased number of crashes.

Table 6-1 Marginal Time Available For Crossing (Inside Approach to Outside Approach)

Major Road	Minor Road	TIME	CRASH
SR-67	Centerton Rd./Rob Hill Rd.	-1.3	40
US-31	9A Road	-0.1	8
SR-37	CR 475 N (Trogon/Trogden Lane)	0.0	0
US-41	CR 200 N. (Frakes St.)	0.6	0
US-41	Old US-41	0.7	1
US-50/150	CR 300 W (Maysville Rd.)	1.1	1
US-41	CR 1000 N. (Freelandville Rd.)	1.3	4
SR-62	McDowell Rd.	1.4	0
US-41	CR 150 S.	3.9	0
US-41	CR 1025 S.	5.1	1
US-41	Campbell Rd./Old State Rd.	6.2	1
SR-37	Victor Pike	6.7	5
US-52	SR-352 (CR 600 S.)	7.3	3
US-41	CR 1100 NE.	7.7	1
SR-63	Division Road (CR 00)	8.1	1
SR-63	Barnhart Rd.	8.9	2
US-31	CR 300 S.	9.2	0
US-50	SR-262/Station Hollow	12.0	3
US-41	CR 350 N. (Grave St.)	12.9	4
US-50/150	SR-257	12.9	15
SR-66	St. Joseph Road	13.0	1
US-41	CR 550 W (Hazelton Rd./McCrary Rd.)	13.4	0
US-41	CR 575 N	17.2	0
SR-62	Posey Co. Line Rd. (CR 1200 E)	18.0	3
SR-63	SR-71	18.3	0
US-41/52	CR700N	20.4	0
US-36	CR 571 E./CR 575 E.	20.8	0
US-50	CR SE 900 E. (Strawberry Hall Rd.)	27.3	0
US-41	CR 500 W (St. Thomas Rd./Essex Rd.)	32.1	0
US-41	CR 400 S.	37.0	0

CHAPTER 7. RESEARCH FINDINGS AND RECOMMENDATIONS

This research provides analyses of accident frequency and severity at intersections where the major road is located on a superelevated curve. The purpose of the study was to determine whether intersections on curves were prone to a greater number of accidents than similar intersections located along tangent sections and, if so, to determine what could be done to improve the relative safety of such intersections.

Two separate intersection samples were examined in the study. The first sample of intersection examined represented the case where the major route and minor route are both two-lane highways. This sample was composed entirely of intersections between state routes. This restriction was imposed to reduce the amount of field data collection required to conduct the statistical analysis. The final sample consisted of 18 intersections located on curves, in addition to 85 tangent intersections. The results of the study indicate that road curvature at the studied 18 intersections did not appear to have a significant impact on neither crash frequency nor their severity. This results has to be taken with a caution due to the limited number of intersections studied.

The second sample in the study consisted of intersections where the major route was a four-lane divided highway and the minor route was a two-lane road. For these intersections, the state-state restriction was lifted because only eight such intersections could be found within the state. By including local and county roads, the sample size was increased to 43 intersections. In addition to these intersections on curves, six additional tangent intersections were included to bring the total sample size to 49. The tangent intersections were selected because they fell in close proximity to the superelevated intersections and had similar geometric characteristics. In contrast to the results of the two-lane sample, for the case where the major road is a four-lane divided highway, curvature appears to have a clear impact on intersection safety. Crashes were found to increase in both frequency and severity at intersections where the four-lane major road was on a superelevated curve. In addition to this result, several other findings provide additional insight into safety at these intersections.

A primary concern for the geometric design of intersections is to allow for adequate sight distance for vehicles attempting to enter or cross the major road. Extreme curvature and superelevation rates have been associated in the past with reductions in sight distance. As such, sight distance was examined as a possible cause for an increase in crashes at intersections located on curves. The sight time, or time from when an approaching vehicle is visible to a vehicle at the stop bar to when the approaching vehicle reaches the collision zone, was determined at each of the intersections in the sample. Additionally, the time required to perform the crossing maneuver at each intersection was determined experimentally, as well. These results were then used in the modeling process to determine the effects of sight distance on intersection safety. Based on the results of these field measurements and statistical analysis, reduced sight distances do not appear to be directly related to curvature. Furthermore, there was no clear pattern between sight distance and crash occurrence within the sample. This does not mean that sight distance is not an important safety factor; it simply confirms that the sight distance provided at each intersection in the sample is sufficient.

In addition to sight distance considerations, crash patterns were examined to gain additional insight into what makes intersections on curves more susceptible to crashes. The number of crashes by collision zone and type were used to identify which types of crashes were overrepresented for the sample on curves. The sample of 43 superelevated intersections experienced a total of 244 crashes over the period from 1997 to 2000. Of these crashes, 73.8% were right-angle collisions, 12.3% were rear-end collisions, 10.7% were single-vehicle collisions, and the remaining 3.2% were sideswipe collisions. These crashes were compared to a sample of 1,378 crashes occurring at similar tangent intersections over the same time period. The tangent sample was obtained using the Indiana state crash database. Intersections on curves experience a significantly higher percentage of right-angle and single-vehicle crashes and a significantly lower percentage of rear-end and sideswipe collisions than intersections on tangent segments.

These crash patterns were broken down further to analyze the effects of darkness and weather effects on safety. When compared to tangent intersections, the intersections on curves experienced a higher proportion of crashes during night conditions, but a lower proportion of crashes during adverse weather conditions. In the case of nighttime crashes, only 20% of crashes in the tangent sample occurred under darkness. For the intersections on curves, 32% of the crashes occurred under darkness. The difference between the two proportions is highly statistically significant, indicating this result did not occur by chance. The combination of curvature and darkness appears to make intersections particularly susceptible to crashes. Lack of sufficient lighting is again a likely cause of this problem. Based on these findings, it is

recommended that lighting installation be considered in cases where an intersection is located on a superelevated curve.

In contrast to the previous result, the number of crashes occurring under inclement weather conditions was greatly underrepresented for the case of intersections on curves. The tangent sample experienced 11.2% of its crashes during rain events and 4.6% during snow events. Conversely, the intersections on curves experienced only 3.3% and 1.2% for the two cases, respectively. Intuitively, one would expect the opposite to be true. This result is possibly due to changes in driver behavior under adverse weather conditions. As weather conditions worsen, drivers may begin to drive more cautiously than under normal weather conditions. When traveling along curves, drivers may tend to drive more slowly if the roads are wet or icy.

While the effects of weather and night conditions can be reasonably explained, some results of the study may require further research. The right-angle collision case for vehicles traveling from the median to the outside approach of the minor leg discussed in Chapter 6 had the highest number of crashes among the crash subtypes. It is not particularly clear what makes this type a greater crash risk than the others. Over 40% of the total crashes for the superelevated sample were of this subtype. Driver perception may again provide an explanation as to why this particular zone is overrepresented in the sample. Theoretically, drivers on the minor road may be overestimating the amount of time available for them to cross the major road. A preliminary investigation was done to examine the difference between the distance a vehicle travels during the sight time and the straight-line distance between a stopped vehicle and one entering the sight zone. Vehicles traveling along the curve may appear to be closer or further away than they actually are based on the location of the stopped vehicle. These distances were approximated using aerial photographs for each of the intersections. Unfortunately, measurement error made it difficult to make accurate estimates and, consequently, no obvious pattern emerged from the data.

Another finding of possible significance was that, in some cases, intersections skewed to the left (from the inside of the curve) tended to experience a significantly large number of crashes. While statistically significant results were not obtained from modeling, it appears that there may be a hazard associated with a combination of curvature and skew. Further research on this issue may prove helpful in explaining why this type of crash is more prevalent.

The key finding of this study is the relationship between crashes and curvature. As degree of curvature is increased, crash frequency also increases significantly within the sample. This result

was found to be highly statistically significant, indicating these results are not due to randomness. There appears to be a relationship between the two variables. Based upon the results of the statistical analysis, critical design values for curvature may be determined by the Indiana Department of Transportation (INDOT).

Figure 7-1 shows the relationship between degree of curve D and safety at an intersection located on a curve. Intersection safety is represented with a crash modification factor (CMF). The CMF value says how many times the frequency of crashes at an intersection on a curve is higher than at an intersection located on a straight segment. The two compared intersections are similar by geometry and traffic. The CMF is calculated with the following formula

$CMF = \exp(0.3918 * D)$, where D is degree of curve. The relationship between the curve radius and the CMF is shown in Figure 7-2. According to the obtained relationships, the frequency of crashes at an intersection on curve is twice higher than on a tangent segment if the degree of curve D is 1.77 or, equivalently, the radius is 3237 feet.

In summary, the most important findings and recommendations for designers and safety managers from this study are:

1. Crashes were found to increase in both frequency and severity at intersections where the four-lane major road was on a curve.
2. Sight distance in the studied sample does not appear to be affected by the horizontal curves. Furthermore, no significant relationship between sight distance and crash frequency was found.
3. Intersections on curves experience a significantly higher percentage of right-angle and single-vehicle crashes and a significantly lower percentage of rear-end and sideswipe collisions than intersections on tangent segments.
4. In comparison to tangent intersections, the intersections on curves experienced a higher proportion of crashes during night conditions. It is recommended that lighting installation be considered in cases where an intersection is located on a curve, particularly where severe superelevation is present.
5. Figures 7-1 and 7-2 show the relationship between intersection safety and the horizontal curvature of the main road. Figure 7-2 indicates a considerable increase in crash frequency when the horizontal curve radius is shorter than 3,000 ft. The obtained relationships will help INDOT determine critical design values for a horizontal curve if an intersection is located on the curve. These design values would apply only to four-lane high-speed rural intersections with STOP signs on crossing roads.

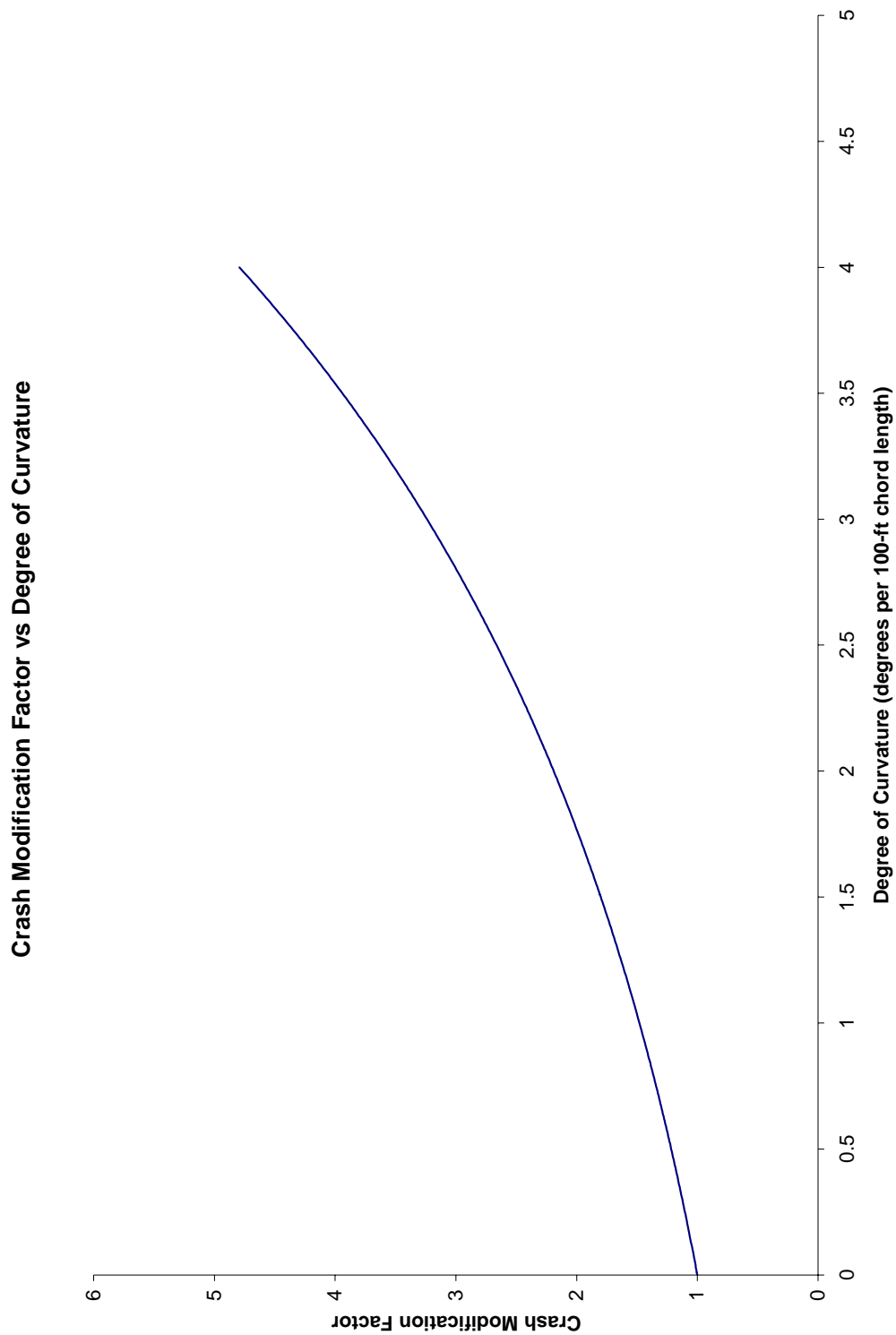


Figure 7-1 Crash Modification Factor vs. Degree of Curvature

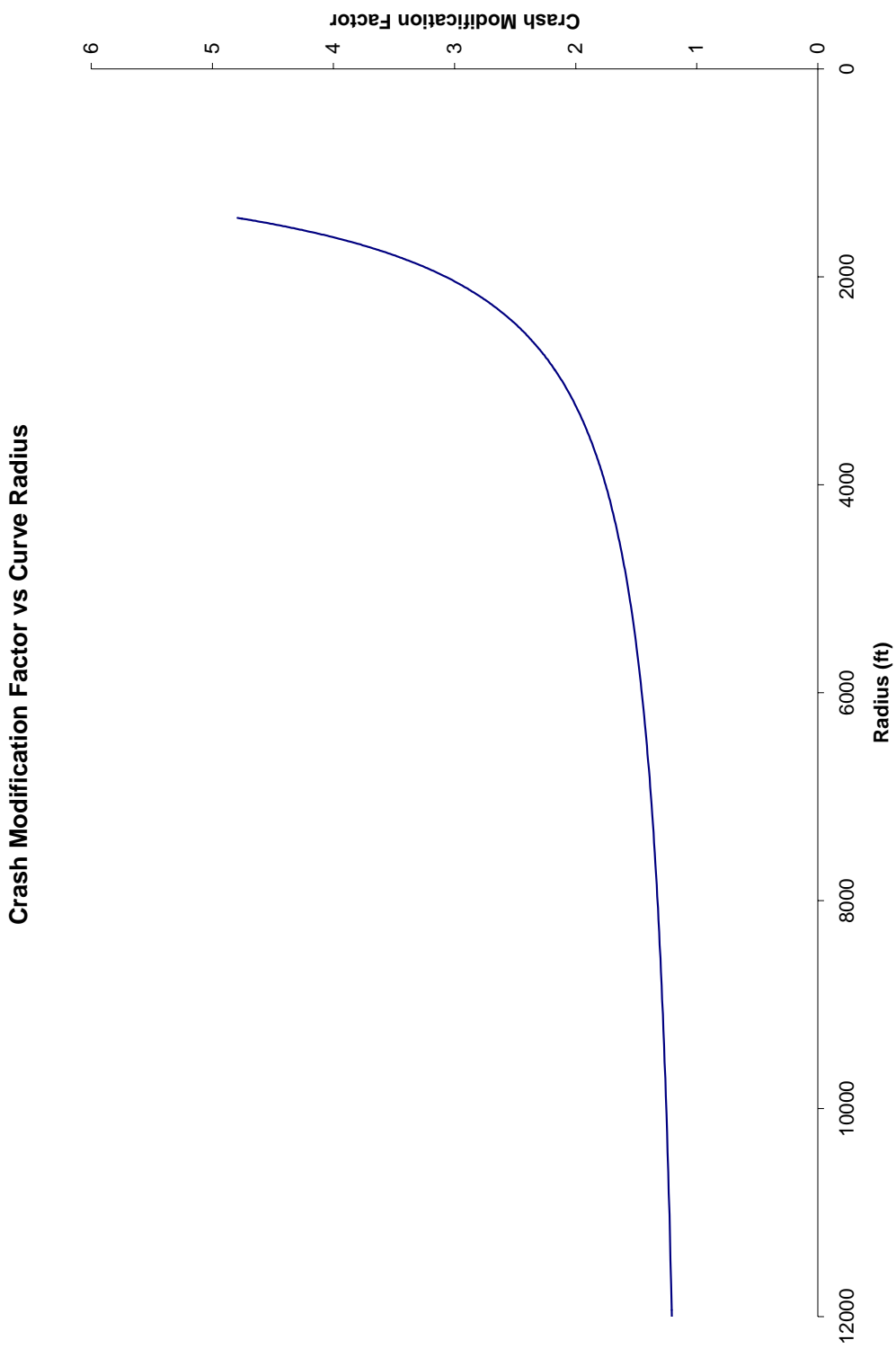


Figure 7-2 Crash Modification Factor vs. Curve Radius

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APPENDIX A. DATA COLLECTION SHEETS

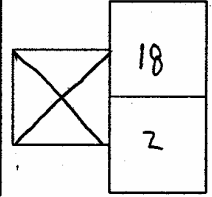
Figure A-1 Intersection of US-41 & CR600W (Benton County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	4.4	5.0	5.0	4.7
LOC1	4.4	5.0	4.7	5.0
LOC2	5.0	5.2	4.5	4.8

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.43	
4.49	
4.22	
4.61	
4.54	

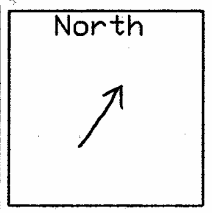


GAP (s)	
t1	t2
16.00	
14.34	
15.79	
15.47	
16.91	
16.13	
16.39	
13.83	
15.85	
15.11	

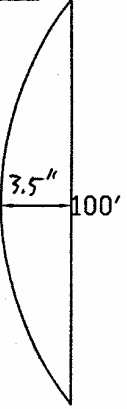
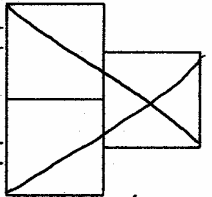
GAP (s)	
t1	t2
20.79	22.66
21.46	21.34
20.59	21.29
20.81	20.78
18.86	22.63
21.29	21.48
20.25	22.76
19.82	21.11
21.10	20.59
20.77	19.97

GAP (s)	
t1	t2
15.79	
14.03	
13.74	
15.84	
14.29	
13.92	
15.36	
14.21	
13.86	
15.29	

GAP (s)	
t1	t2



COUNTS (veh):
 PERIOD (min):
 120



DATE: 05/20/03
 TIME: 10:30 AM
 WEATHER: Cloudy
 DISTRICT: Crawfordsville
 COUNTY: Benton
 OBSERVER: PS
 MAJOR ROAD: US-41/52
 MINOR ROAD: CR600W
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

Figure A-2 Intersection of US-41 & CR700N (Benton County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	4.5	4.1	3.8	4.0
LOC1	4.9	4.7	3.5	4.6
LOC2	4.6	3.6	2.8	3.8

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
5.17	4.55
4.85	4.60
4.72	4.50
4.69	4.74
4.54	4.59

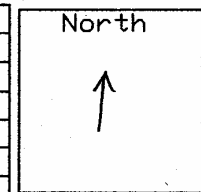
GAP (s)	
t1	t2
36.78	
34.54	
32.66	
33.07	
35.15	
38.05	
33.15	
34.84	
33.31	
34.67	

GAP (s)	
t1	t2
15.88	18.41
15.80	19.07
17.93	18.39
16.74	18.42
16.35	19.29
16.94	17.34
16.48	18.63
16.51	19.87
15.91	18.14
16.20	19.67

GAP (s)	
t1	t2
31.49	30.21
33.80	29.43
31.65	29.75
32.44	29.77
33.90	28.86
32.76	30.05
34.68	30.92
34.07	29.44
32.29	29.37
33.42	30.18

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
10.87	
10.88	
12.10	
10.70	
12.79	
11.86	
10.69	
11.78	
11.42	
11.33	



DATE: 05/20/03
 TIME: 8:30 AM
 WEATHER: Cloudy
 DISTRICT: Crawfordsville
 COUNTY: Benton
 OBSERVER: PS
 MAJOR ROAD: US-41/52
 MINOR ROAD: CR700N
 SPEED LIMIT: 55
 CONTROL: TWSL
 VERTICAL CURVE: N₀

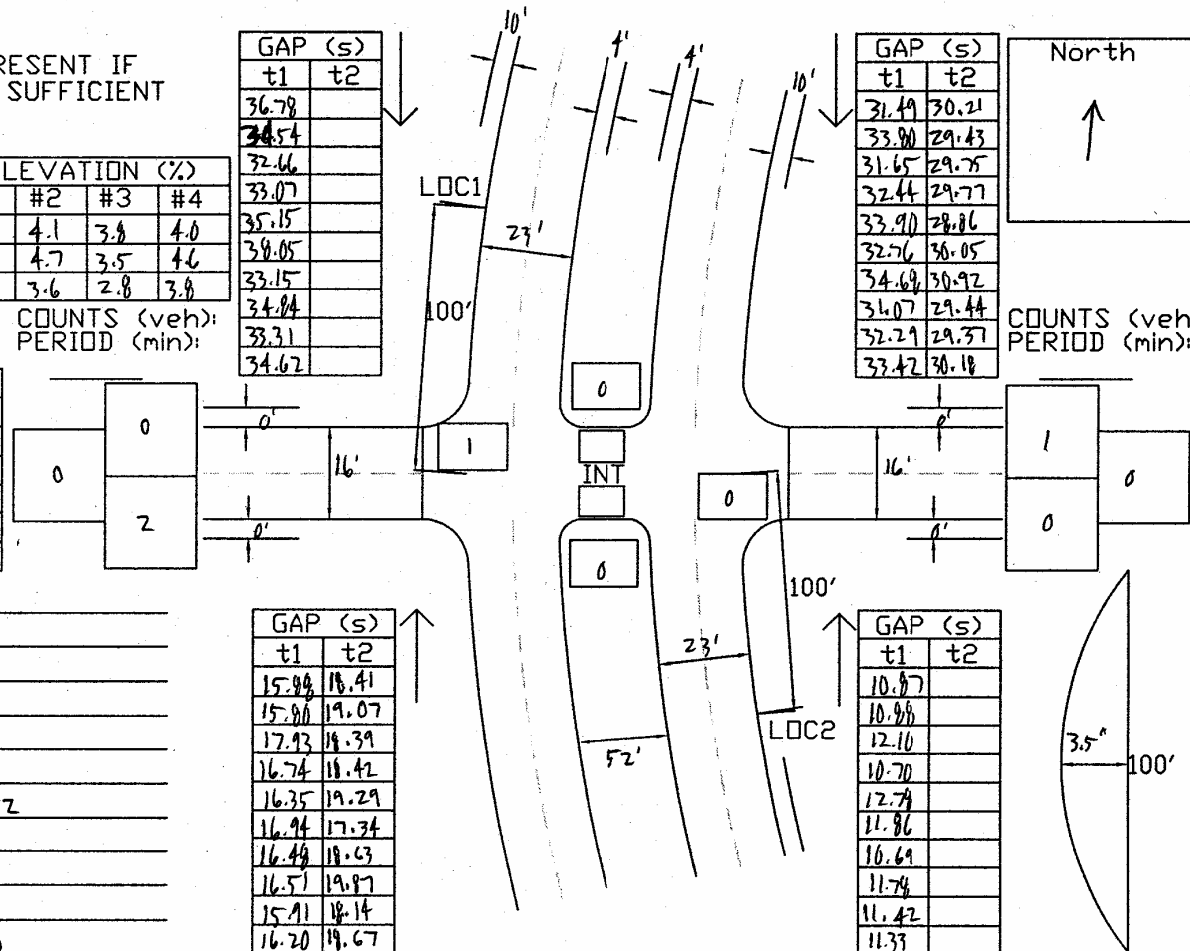


Figure A-3 Intersection of US-52 & SR-352/CR600S (Benton County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	1.0	0.9	1.2	1.3
LOC1	0.6	0.8	0.7	0.7
LOC2	1.7	0.2	0.4	1.5

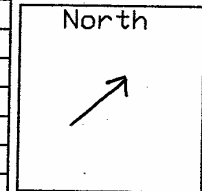
COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.76	4.88
4.94	4.79
4.92	4.69
4.65	4.93
4.55	4.82

GAP (s)	
t1	t2
31.40	
29.31	
31.12	
31.37	
31.38	
29.76	
30.67	
30.88	
31.10	
29.74	

GAP (s)	
t1	t2
21.56	16.10
19.17	16.44
21.26	16.16
21.50	17.72
21.02	17.18
19.82	16.39
20.64	16.62
19.46	16.49
21.21	18.23
20.88	17.80

COUNTS (veh):
 PERIOD (min):



DATE: 05/21/03
 TIME: 9:00 AM
 WEATHER: Clear
 DISTRICT: Crawfordsville
 COUNTY: Benton
 OBSERVER: PS
 MAJOR ROAD: US-52
 MINOR ROAD: SR-352/CR600S
 SPEED LIMIT: 55
 CONTROL: TWFL
 VERTICAL CURVE: No

GAP (s)	
t1	t2
23.32	28.36
25.26	29.11
24.51	27.49
25.23	28.82
22.35	30.09
25.59	28.40
24.63	27.63
24.29	29.80
23.67	27.27
25.01	28.69

GAP (s)	
t1	t2
12.03	
11.79	
10.77	
10.53	
12.17	
10.87	
9.64	
11.19	
10.35	
12.32	

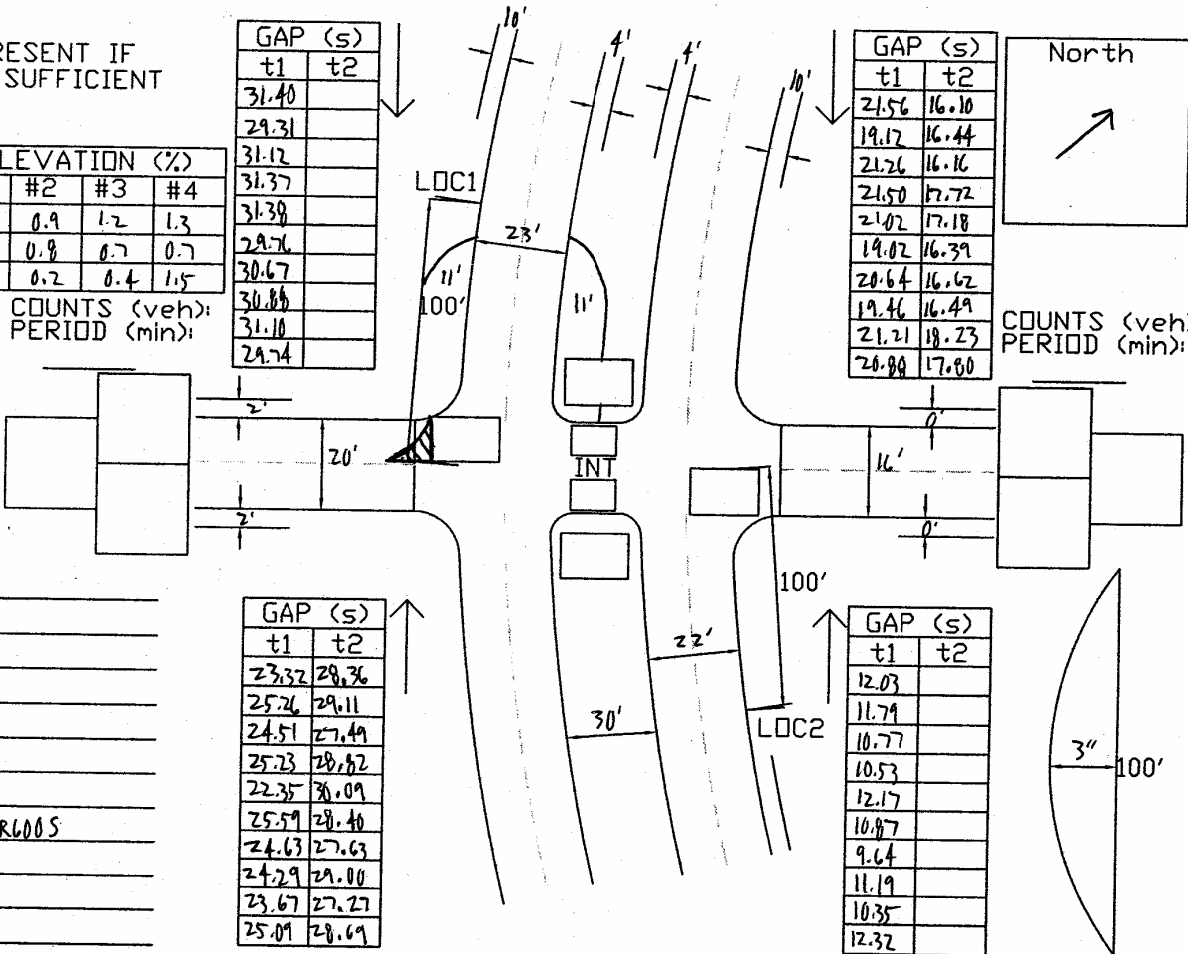


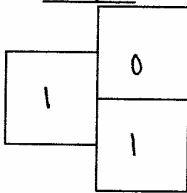
Figure A-5 Intersection of US-36 & CR571E/CR575E (Hendricks County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

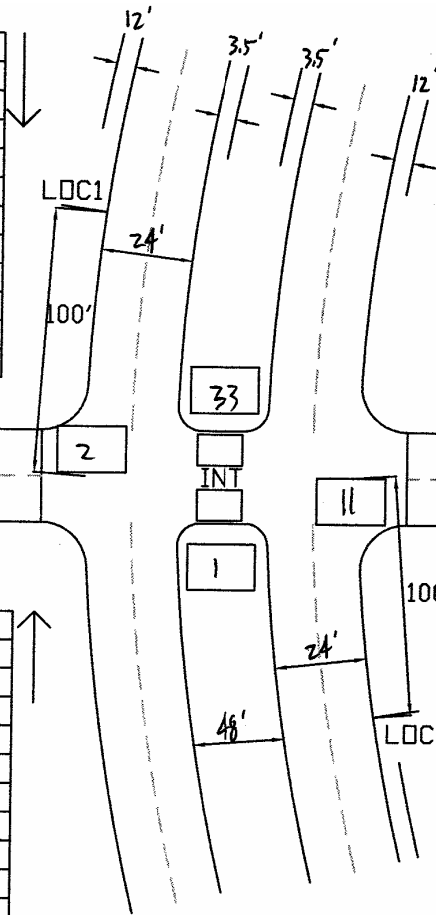
SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	3.6	4.2	4.1	4.1
LOC1	3.8	4.5	4.3	5.0
LOC2	4.1	3.6	4.2	4.3

COUNTS (veh):
 PERIOD (min):
 120

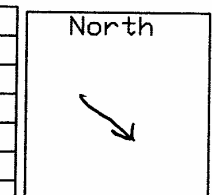
GAP (s)	
t1	t2
4.61	4.30
4.65	4.46
4.63	4.44
4.82	4.76
4.85	4.81



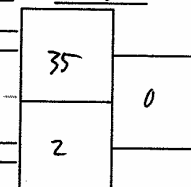
GAP (s)	
t1	t2
27.01	
28.89	
30.56	
29.11	
26.97	
29.99	
27.32	
29.66	
31.30	
29.77	



GAP (s)	
t1	t2
31.27	29.40
29.01	30.38
31.12	29.70
32.12	29.62
32.41	30.49
33.02	31.07
32.62	31.33
28.56	30.46
31.80	29.52
31.46	29.28

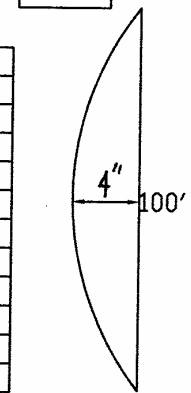


COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
15.47	16.17
14.51	15.39
13.45	15.05
14.77	16.73
15.22	15.08
15.22	15.92
13.75	15.84
15.46	16.37
14.27	15.26
15.69	15.45

GAP (s)	
t1	t2
14.93	
15.83	
16.12	
16.42	
16.93	
15.96	
15.07	
15.30	
13.91	
14.44	



DATE: 06/25/03
 TIME: 11:00 AM
 WEATHER: Clear
 DISTRICT: Crawfordsville
 COUNTY: Hendricks
 OBSERVER: PS
 MAJOR ROAD: US-36
 MINOR ROAD: CR571E/CR575E
 SPEED LIMIT: 55
 CONTROL: TWISL
 VERTICAL CURVE: Crest

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	5.6	4.8	1.5	2.4
LOC1	4.8	5.0	2.1	3.3
LOC2	5.1	4.5	2.1	3.2

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.96	4.78
4.68	4.66
4.70	4.58
4.72	4.86
4.65	4.69

GAP (s)	
t1	t2
35.44	
36.18	
36.64	
34.82	
33.69	
37.29	
36.40	
40.02	
35.29	
37.26	

GAP (s)	
t1	t2
33.44	29.40
34.18	27.98
31.54	26.87
29.39	26.91
30.56	27.47
33.25	27.58
32.62	28.08
31.45	28.33
33.09	26.62
32.66	27.64

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
15.74	19.25
15.32	20.08
16.31	20.31
16.01	20.40
15.92	20.22
16.56	19.66
16.04	19.48
14.82	19.37
14.58	18.86
16.35	20.05

GAP (s)	
t1	t2
13.08	
12.13	
12.13	
12.83	
12.95	
13.03	
11.47	
12.58	
13.21	

DATE: 05/22/03
 TIME: 3:00 PM
 WEATHER: Clear
 DISTRICT: Crawfordsville
 COUNTY: Vermillion
 OBSERVER: ps
 MAJOR ROAD: SR-63
 MINOR ROAD: SR-71
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

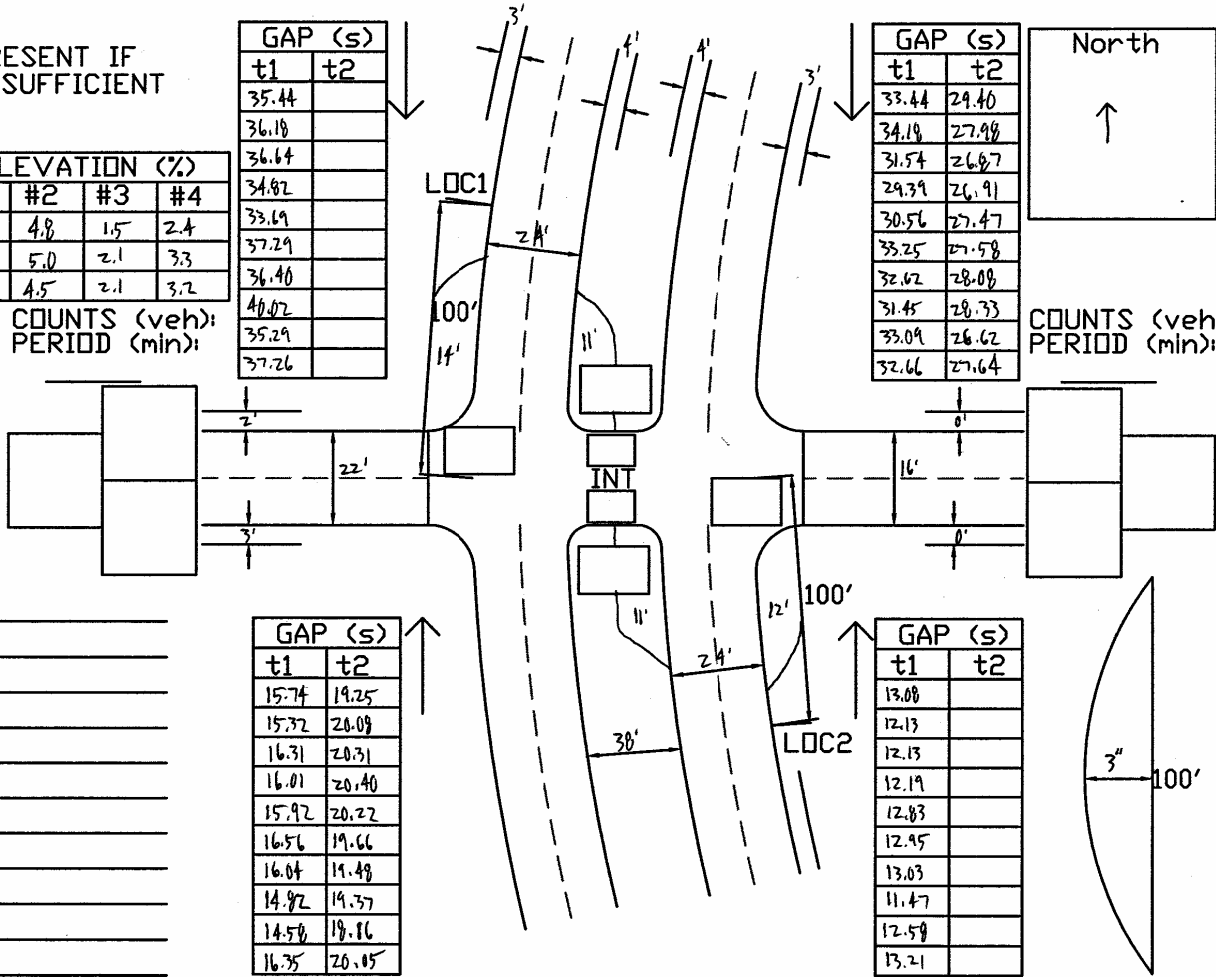


Figure A-6 Intersection of SR-63 & SR-71 (Vermillion County)

Figure A-8 Intersection of SR-63 & Barnhart Rd. (Vigo County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	2.5	2.5	2.7	2.3
LOC1	2.5	2.5	2.7	2.3
LOC2	2.5	2.5	2.7	2.3

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.96	4.63
4.75	4.88
4.88	5.26
4.52	5.05
4.79	4.97

0	8
61	

GAP (s)	
t1	t2
24.86	
27.51	
25.69	
26.11	
25.79	
27.58	
25.12	
26.86	
24.15	
24.20	

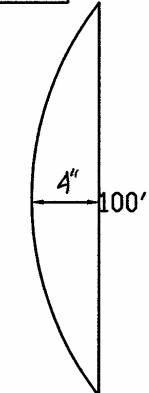
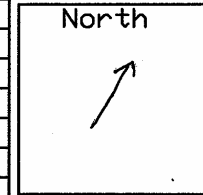
GAP (s)	
t1	t2
14.69	22.67
15.50	23.79
16.22	22.47
15.11	22.53
16.76	23.18
16.54	22.49
16.63	23.87
15.60	22.52
15.92	22.88
15.42	22.07

GAP (s)	
t1	t2
20.42	18.30
21.93	19.12
21.66	19.49
21.84	19.32
20.97	18.27
26.93	18.85
22.28	20.28
21.49	16.19
20.78	17.16
21.19	19.91

COUNTS (veh):
 PERIOD (min):
 120

2	1
6	

GAP (s)	
t1	t2
11.86	
12.81	
10.75	
13.03	
11.50	
12.48	
11.64	
10.57	
12.35	
12.10	



DATE: 05/22/03
 TIME: 10:00 AM
 WEATHER: Clear
 DISTRICT: Crawfordsville
 COUNTY: Vigo
 OBSERVER: PS
 MAJOR ROAD: SR-63
 MINOR ROAD: Barnhart Rd.
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

Figure A-10 Intersection of SR-63 & SR263 S. Jct. (Warren County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	5.3	5.5	5.2	5.2
LOC1	5.2	5.3	5.2	5.1
LOC2	5.1	5.7	5.3	5.1

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.89	
4.76	
4.92	
4.69	
4.73	

GAP (s)	
t1	t2
33.65	
35.32	
33.52	
37.68	
34.07	
34.99	
35.22	
37.68	
39.56	
37.78	

GAP (s)	
t1	t2
29.86	
31.46	
32.98	
31.04	
30.63	
32.69	
30.42	
33.47	
31.91	
31.43	

COUNTS (veh):
 PERIOD (min):

DATE: 05/23/03
 TIME: 10:00 AM
 WEATHER: cloudy
 DISTRICT: Crawfordsville
 COUNTY: Warren
 OBSERVER: PS
 MAJOR ROAD: SR-63
 MINOR ROAD: SR-263 (S. Jct)
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: N/A

GAP (s)	
t1	t2
16.16	18.19
15.11	20.73
17.20	19.43
16.76	20.20
17.12	19.77
15.86	18.91
16.67	19.51
15.08	19.79
15.06	20.07
15.55	18.82

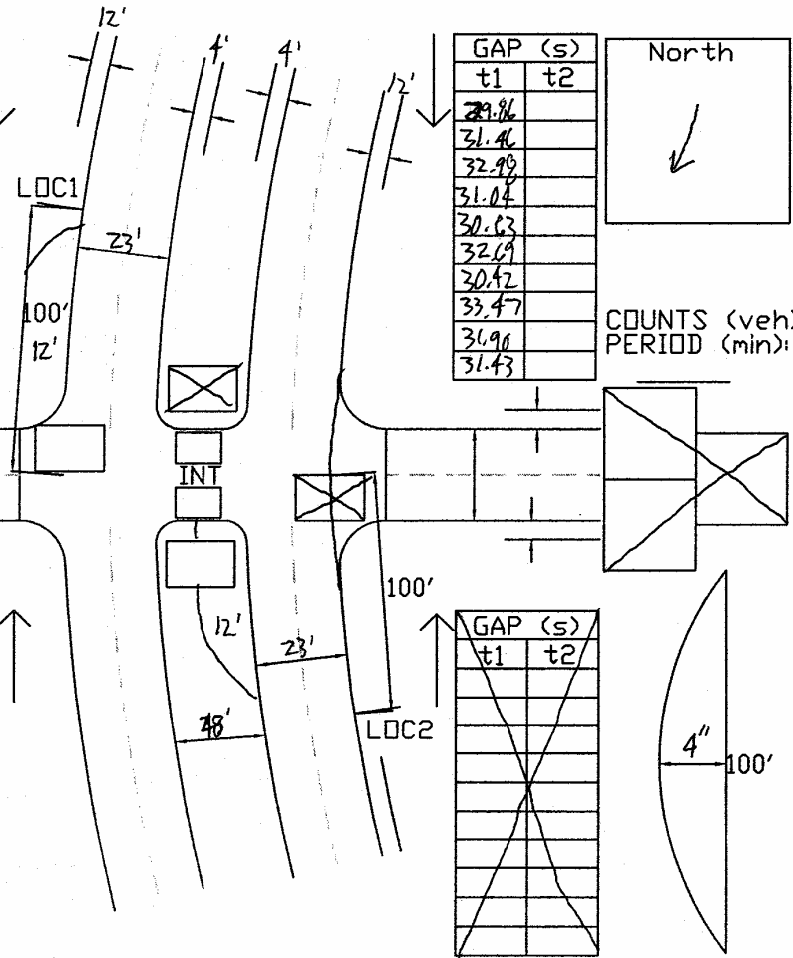


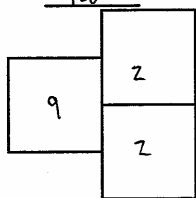
Figure A-11 Intersection of SR-63 & Division Rd. (Warren County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

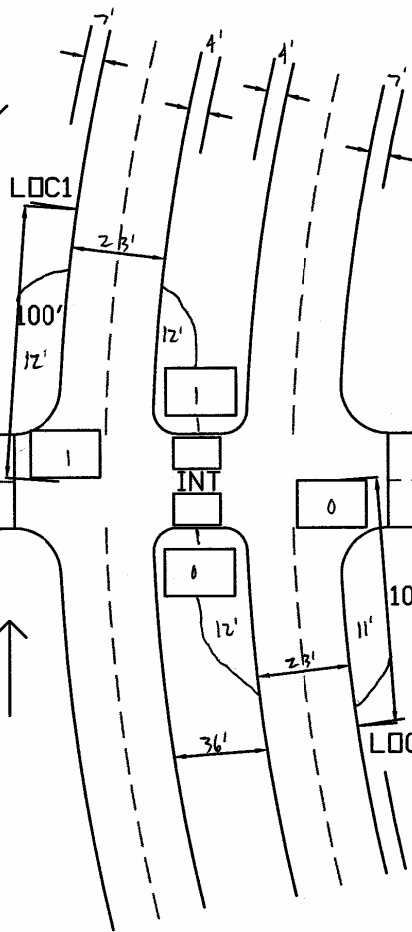
SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	5.6	5.5	5.4	5.5
LOC1	5.5	5.2	5.3	5.5
LOC2	5.4	5.5	5.6	5.5

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
5.50	5.10
5.40	5.44
5.46	5.20
5.70	5.26
5.18	5.12



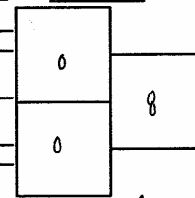
GAP (s)	
t1	t2
19.51	
20.88	
20.03	
23.31	
21.37	
21.53	
21.83	
18.31	
21.74	
19.92	



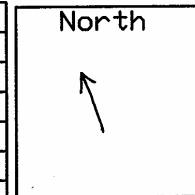
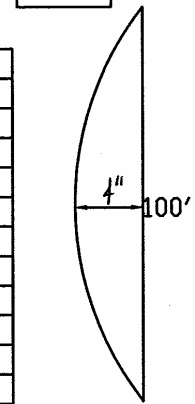
GAP (s)	
t1	t2
17.63	72.36
17.74	70.41
18.80	74.69
16.89	68.77
18.18	67.92
18.50	71.81
18.30	70.29
17.58	69.81
17.67	66.77
17.62	72.18

GAP (s)	
t1	t2
20.78	20.58
18.89	19.41
18.40	18.27
21.61	19.16
19.70	19.12
20.32	18.42
19.60	18.63
18.43	17.87
17.60	18.29
17.63	17.40

COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
9.29	
9.99	
9.19	
8.79	
8.89	
9.75	
9.46	
9.22	
9.41	
9.61	



DATE: 05/23/03
 TIME: 11:30 AM
 WEATHER: Cloudy
 DISTRICT: Crawfordville
 COUNTY: Warren
 OBSERVER: ps
 MAJOR ROAD: SR-63
 MINOR ROAD: Division Rd. (CR 00)
 SPEED LIMIT: 55
 CONTROL: TWSL
 VERTICAL CURVE: No

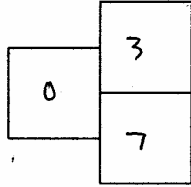
Figure A-12 Intersection of US-31 & CR300S (Fulton County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	3.8	3.8	6.4	6.4
LOC1	3.8	3.8	4.3	4.3
LOC2	4.1	4.9	3.9	3.9

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.76	4.66
4.78	4.87
4.93	4.68
5.22	5.08
5.13	5.16

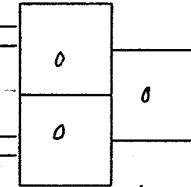


GAP (s)	
t1	t2
20.69	
22.80	
22.46	
23.88	
22.75	
24.06	
22.94	
22.79	
22.30	
23.19	

GAP (s)	
t1	t2
27.29	32.51
25.63	33.44
25.99	34.47
26.04	33.07
27.29	31.99
26.64	32.64
25.79	33.46
25.48	32.28
26.23	30.79
25.97	31.46

GAP (s)	
t1	t2
20.54	18.87
21.67	19.60
21.97	19.77
22.62	20.25
22.49	18.41
21.36	18.24
22.43	19.50
20.25	19.27
22.03	19.09
21.89	18.50

COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
25.22	
24.95	
25.83	
25.05	
24.46	
24.28	
25.79	
25.68	
24.60	
24.85	

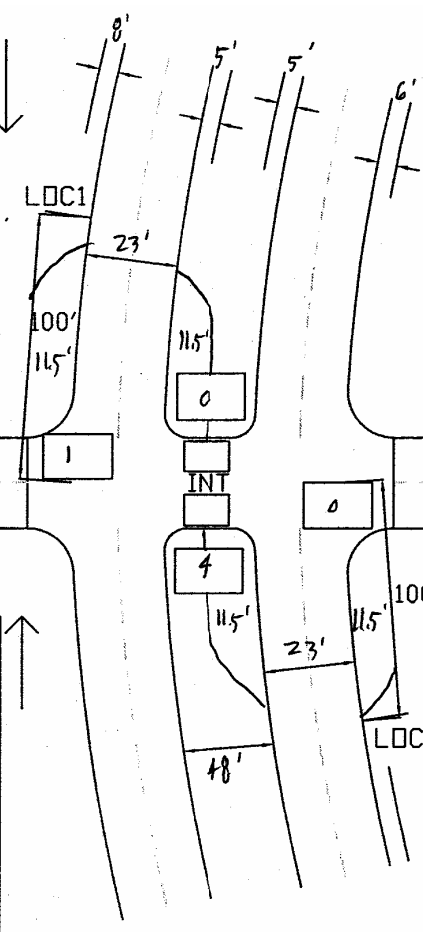
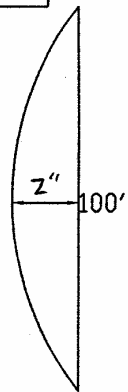
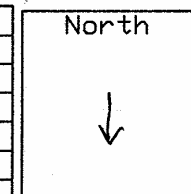


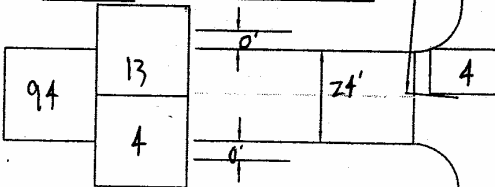
Figure A-13 Intersection of US-31 & 9A Rd. (Marshall County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	5.0	5.6	4.5	4.0
LOC1	5.7	5.7	4.9	4.9
LOC2	2.4	3.2	2.4	1.9

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
5.18	5.14
5.36	5.23
5.09	5.10
5.20	5.28
5.23	5.17

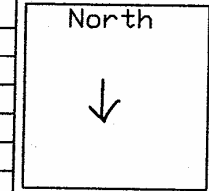


GAP (s)	
t1	t2
13.08	
12.63	
13.06	
15.76	
12.67	
13.19	
12.78	
12.54	
13.86	
13.49	

GAP (s)	
t1	t2
40.77	39.45
38.49	40.76
40.65	39.29
39.18	39.88
37.33	38.47
38.76	40.50
39.42	41.47
40.11	40.11
38.20	38.39
37.92	42.26

GAP (s)	
t1	t2
12.78	11.21
12.97	9.68
13.43	11.50
13.28	10.68
14.87	10.07
13.09	10.00
13.47	9.42
13.62	10.40
13.01	9.88
12.84	10.25

COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
39.30	
38.86	
40.55	
37.22	
38.14	
44.20	
41.36	
39.53	
41.20	
40.69	

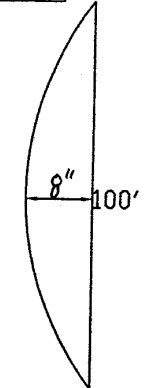
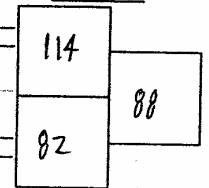


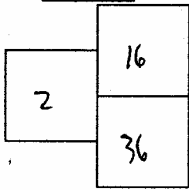
Figure A-14 Intersection of US-31 & Tyler Rd. (St. Joseph County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	1.8	1.8	2.4	2.0
LOC1	1.8	1.8	1.9	1.9
LOC2	1.7	1.9	1.5	1.6

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.76	4.49
4.70	4.48
4.66	4.89
4.86	4.62
4.78	4.53

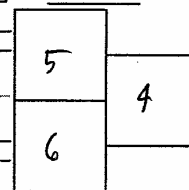


GAP (s)	
t1	t2
68.62	
72.12	
22.44	
70.70	
71.20	
69.39	
72.06	
71.15	
73.53	
70.02	

GAP (s)	
t1	t2
52.26	54.21
53.73	52.37
53.18	50.86
51.06	52.25
54.22	51.07
49.65	53.11
54.37	52.36
52.42	50.49
53.91	54.23
50.08	51.76

GAP (s)	
t1	t2
69.44	70.29
73.52	72.66
72.21	72.47
71.77	73.29
69.84	71.43
70.11	72.21
74.66	70.86
73.38	71.54
72.47	71.56
71.20	71.24

COUNTS (veh):
 PERIOD (min):



GAP (s)	
t1	t2
53.28	
51.09	
53.69	
50.23	
53.72	
55.12	
54.81	
52.86	
49.41	
51.96	

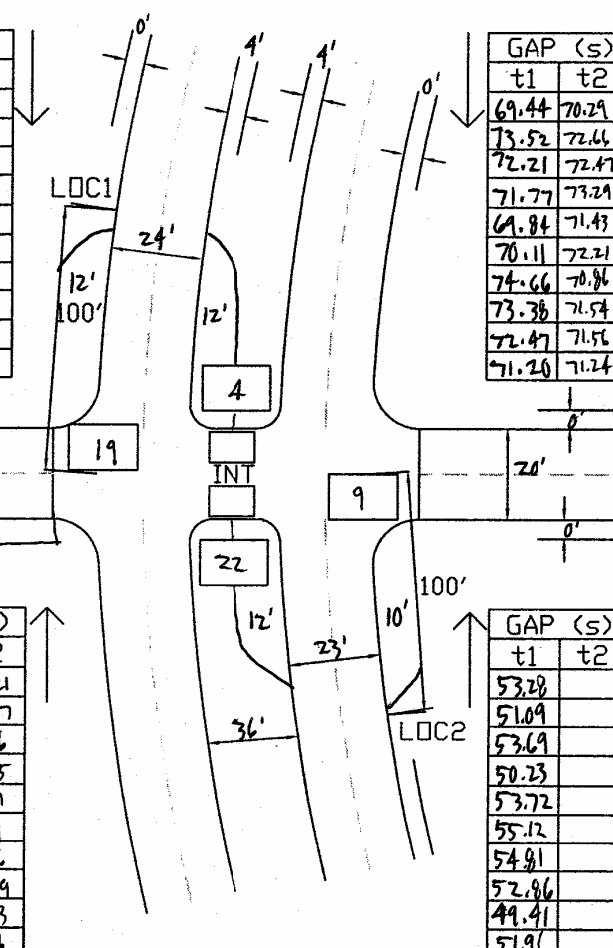
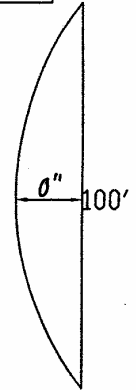
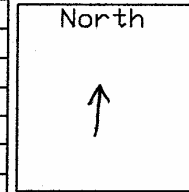


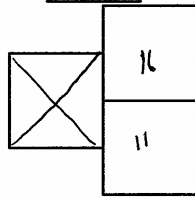
Figure A-16 Intersection of US-50 & Stoops Rd. (Dearborn County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

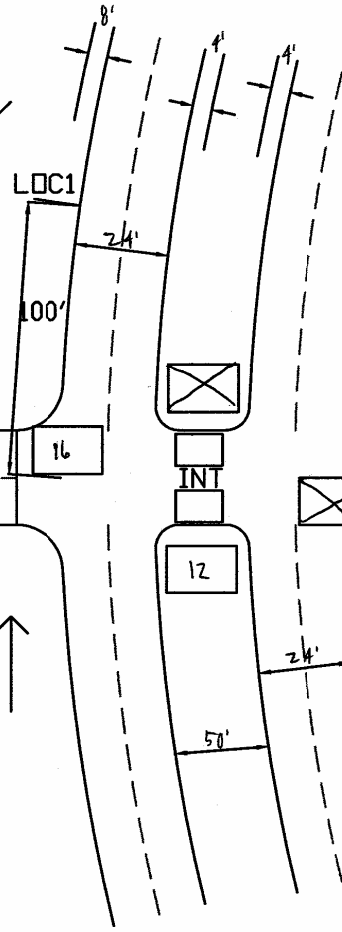
SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	4.6	5.4	3.9	5.3
LOC1	4.6	4.9	3.9	5.2
LOC2	4.5	5.7	4.0	5.5

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.22	
4.12	
4.30	
3.63	
3.78	

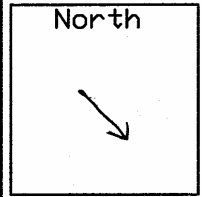


GAP (s)	
t1	t2
29.38	
26.42	
28.07	
29.16	
26.88	
26.66	
28.10	
26.63	
25.25	
27.70	

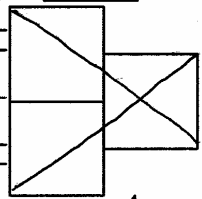


GAP (s)	
t1	t2
17.86	23.53
17.85	19.88
16.93	21.38
17.10	22.59
18.53	20.56
17.44	21.08
17.65	22.49
16.71	21.75
17.74	23.22
16.33	20.87

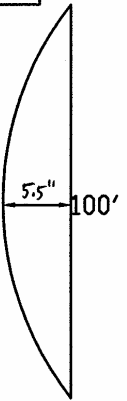
GAP (s)	
t1	t2
24.58	
23.62	
25.35	
24.71	
24.46	
25.90	
25.21	
22.95	
22.96	
23.42	



COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2



DATE: 07/12/03
 TIME: 4:00 PM
 WEATHER: Clear
 DISTRICT: Seymour
 COUNTY: Dearborn
 OBSERVER: PS
 MAJOR ROAD: US-50
 MINOR ROAD: Stoops Rd.
 SPEED LIMIT: 55
 CONTROL: TWFL
 VERTICAL CURVE: N0

Figure A-17 Intersection of US-50 & Texas Gas Rd. (Dearborn County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	3.1	4.6	3.1	5.0
LOC1	4.4	5.2	3.4	4.8
LOC2	3.4	5.3	3.2	4.4

GAP (s)		COUNTS (veh): PERIOD (min):
t1	t2	
4.24		120 25 25
4.05		
4.10		
3.88		
4.17		

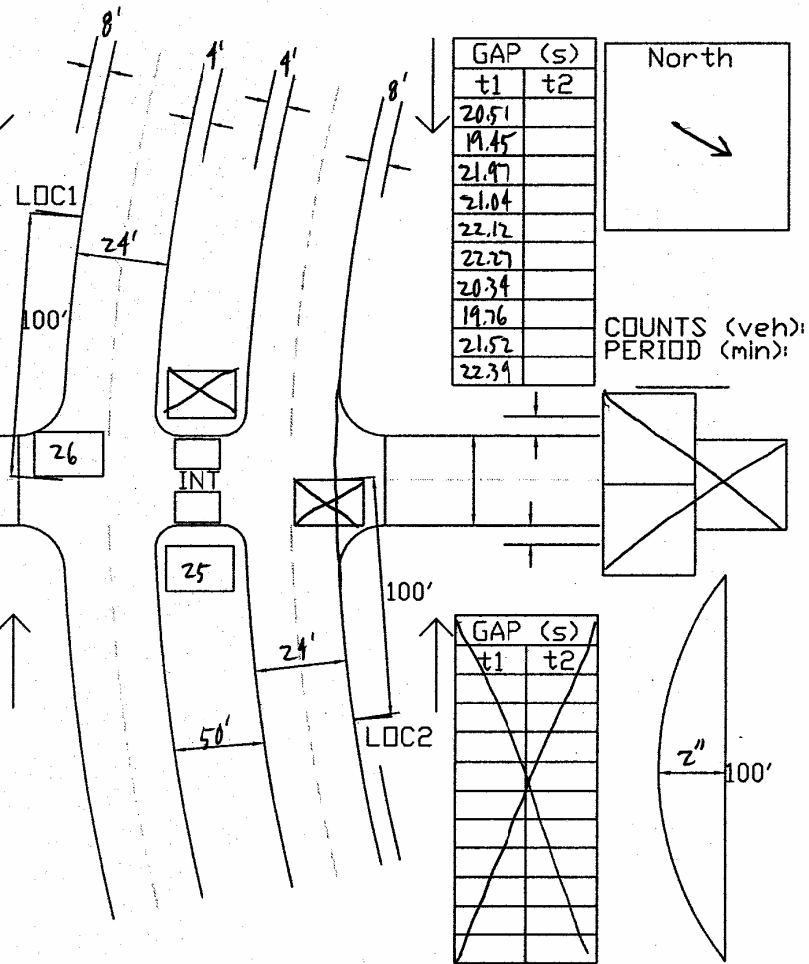
GAP (s)	
t1	t2
23.49	
24.55	
24.04	
22.48	
24.59	
23.07	
22.79	
23.95	
23.06	
23.69	

GAP (s)	
t1	t2
23.67	24.84
22.84	21.20
24.63	22.00
22.23	24.82
24.44	24.46
22.59	24.02
24.29	24.76
21.56	24.89
21.86	21.04
21.53	21.64

GAP (s)	
t1	t2
20.51	
19.45	
21.97	
21.04	
22.12	
22.27	
20.34	
19.76	
21.52	
22.34	

GAP (s)	
t1	t2

DATE: 07/12/03
 TIME: 1:30 PM
 WEATHER: Cloudy
 DISTRICT: Seymour
 COUNTY: Dearborn
 OBSERVER: PS
 MAJOR ROAD: US-50
 MINOR ROAD: Texas Gas Rd.
 SPEED LIMIT: 55
 CONTROL: TWSL
 VERTICAL CURVE: No



COUNTS (veh):
PERIOD (min):

Figure A-18 Intersection of US-50 & SR-262/Station Hollow Rd. (Dearborn County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	2.2	3.2	1.4	2.9
LOC1	3.3	3.7	0.7	4.5
LOC2	1.9	2.6	1.6	3.3

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.15	4.36
4.08	4.35
4.28	4.66
3.85	4.47
3.84	4.51

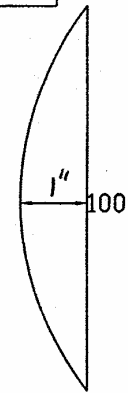
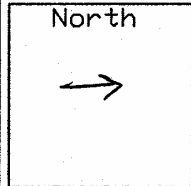
GAP (s)	
t1	t2
42.87	
46.97	
43.53	
44.66	
42.21	
42.44	
45.09	
43.74	
44.29	
41.89	

GAP (s)	
t1	t2
9.52	25.95
9.29	26.59
8.14	24.96
10.08	22.71
8.97	28.42
9.01	25.49
8.97	25.15
9.54	24.78
8.92	27.29
9.55	25.62

GAP (s)	
t1	t2
33.28	22.93
31.04	20.29
37.98	19.26
29.54	19.24
32.91	20.96
35.46	19.45
33.04	20.20
28.96	20.76
32.27	21.88
31.17	20.10

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
9.56	
9.21	
8.16	
8.16	
9.86	
8.28	
9.31	
9.19	
9.40	
10.89	



DATE: 07/12/03
 TIME: 6:00 PM
 WEATHER: Clear
 DISTRICT: Seymour
 COUNTY: Dearborn
 OBSERVER: BS
 MAJOR ROAD: US-50
 MINOR ROAD: SR-262 / Station Hollow
 SPEED LIMIT: 55
 CONTROL: TWOL
 VERTICAL CURVE: Crest

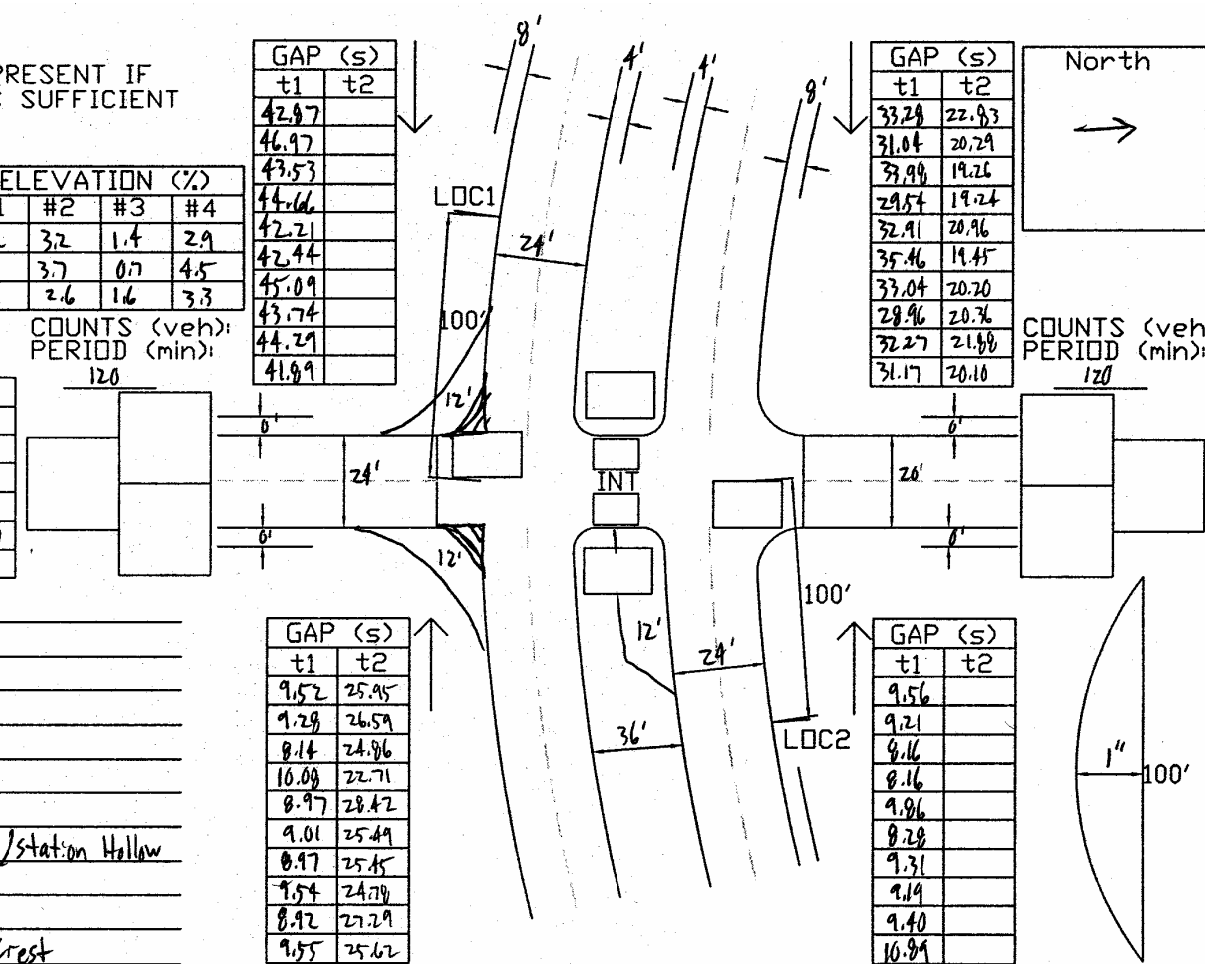


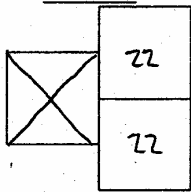
Figure A-19 Intersection of US-421 & Old SR-62 (Jefferson County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

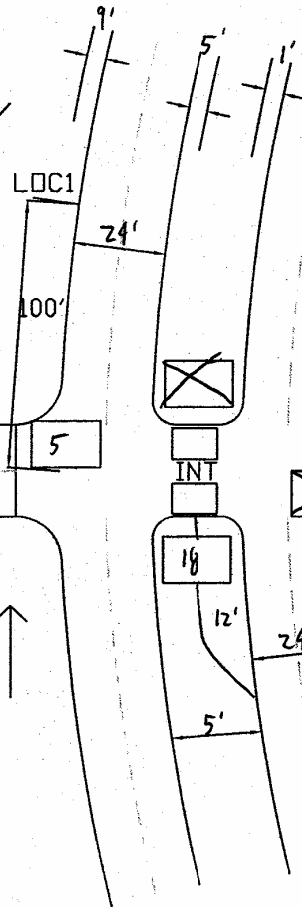
SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	5.5	6.7	6.8	7.6
LOC1	6.2	7.6	7.5	7.4
LOC2	7.1	7.3	6.5	6.6

COUNTS (veh):
 PERIOD (min):
 120

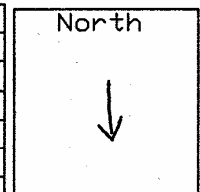
GAP (s)	
t1	t2
4.87	
4.96	
4.75	
4.85	
5.01	



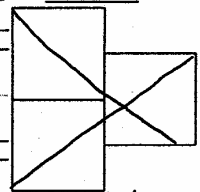
GAP (s)	
t1	t2
11.56	
11.70	
11.15	
12.49	
11.72	
12.40	
11.37	
11.56	
11.91	
11.84	



GAP (s)	
t1	t2
11.07	
11.81	
10.71	
11.17	
10.38	
11.32	
11.40	
11.98	
11.50	
9.88	

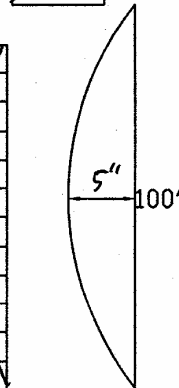


COUNTS (veh):
 PERIOD (min):



GAP (s)	
t1	t2
30.68	32.09
31.77	29.33
27.65	31.32
28.10	30.78
30.74	29.76
30.94	31.79
27.65	30.92
31.06	30.45
31.07	31.94
30.46	30.03

GAP (s)	
t1	t2



DATE: 07/13/03
 TIME: 8:30 AM
 WEATHER: Clear
 DISTRICT: Seymour
 COUNTY: Jefferson
 OBSERVER: PS
 MAJOR ROAD: US-421
 MINOR ROAD: Old SR-62
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

Figure A-20 Intersection of SR-37 & Victor Pike (Monroe County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	3.5	4.7	4.2	5.2
LOC1	3.6	4.2	3.7	4.3
LOC2	3.5	3.9	2.9	3.9

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.20	4.33
4.76	4.10
4.06	4.02
4.18	4.21
4.26	4.09

20	54
	148

GAP (s)	
t1	t2
15.02	
15.92	
15.80	
14.64	
15.25	
15.47	
14.92	
16.63	
16.80	
16.50	

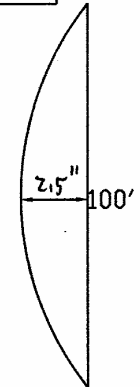
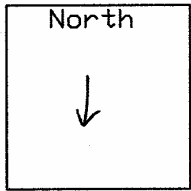
GAP (s)	
t1	t2
14.09	17.67
14.72	17.59
15.74	16.72
16.24	17.67
16.62	18.08
16.36	17.44
15.88	17.48
16.06	18.60
16.92	17.95
16.64	17.72

GAP (s)	
t1	t2
15.02	15.57
16.39	15.29
14.98	15.86
16.06	14.57
15.62	16.47
15.16	15.26
16.92	15.00
16.58	14.39
16.90	15.40
15.96	15.18

COUNTS (veh):
 PERIOD (min):
 120

17	58
31	

GAP (s)	
t1	t2
15.91	
16.54	
16.71	
17.17	
16.55	
16.56	
16.60	
17.27	
16.02	
15.19	



DATE: 07/16/03
 TIME: 7:30 AM
 WEATHER: Clear
 DISTRICT: Vincennes
 COUNTY: Monroe
 OBSERVER: PS
 MAJOR ROAD: SR-37
 MINOR ROAD: Victor Pike
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

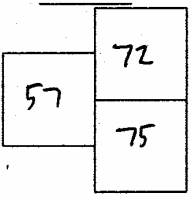
Figure A-23 Intersection of SR-67 & Centerton Rd./Rob Hill Rd. (Morgan County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	2.8	5.0	2.9	3.6
LOC1	1.1	4.3	2.3	3.1
LOC2	2.8	4.9	2.7	3.4

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.60	5.25
4.48	5.20
4.63	5.18
4.59	5.38
4.42	5.40

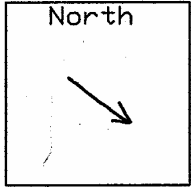


GAP (s)	
t1	t2
54.49	
55.36	
58.93	
52.87	
55.80	
53.42	
56.33	
54.75	
52.11	
55.08	

GAP (s)	
t1	t2
20.99	30.35
22.99	28.43
21.86	27.16
21.68	26.62
19.81	28.38
22.31	29.57
22.33	27.72
26.40	29.05
21.87	20.11
21.13	28.32

GAP (s)	
t1	t2
34.86	21.62
35.25	26.27
34.58	18.59
36.78	19.21
36.40	19.08
36.31	20.31
34.38	20.42
35.67	19.80
36.05	19.76
32.75	20.28

COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
15.26	
14.56	
13.87	
13.84	
14.74	
14.09	
15.79	
13.91	
14.72	
14.60	

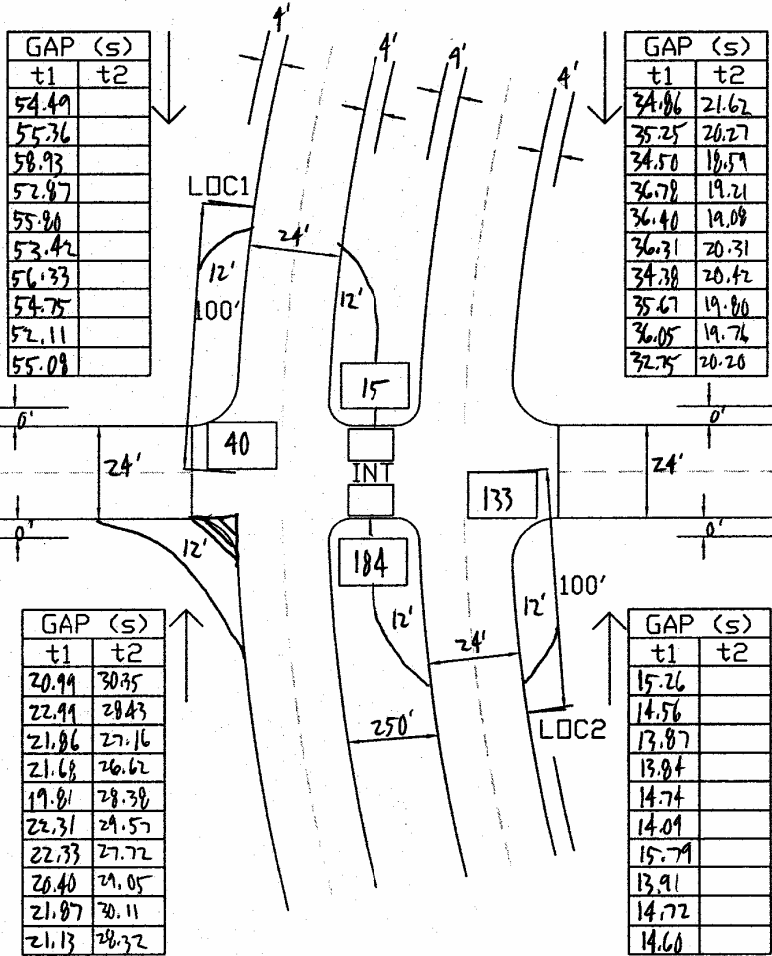
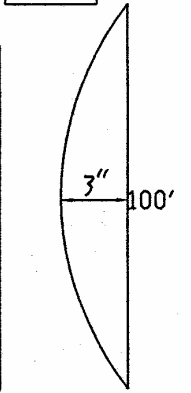


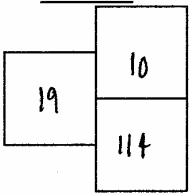
Figure A-24 Intersection of US-50/150 & CR300W (Daviness County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	3.5	3.5	3.5	3.7
LOC1	3.5	3.5	3.0	3.3
LOC2	3.7	4.2	3.5	3.5

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.69	4.95
4.67	4.92
4.61	5.08
4.55	4.79
4.67	4.84

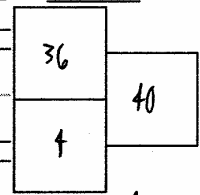
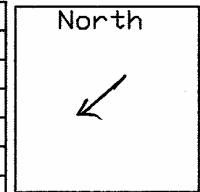


GAP (s)	
t1	t2
11.73	
9.00	
10.10	
11.36	
10.21	
9.99	
10.57	
10.00	
9.78	
9.86	

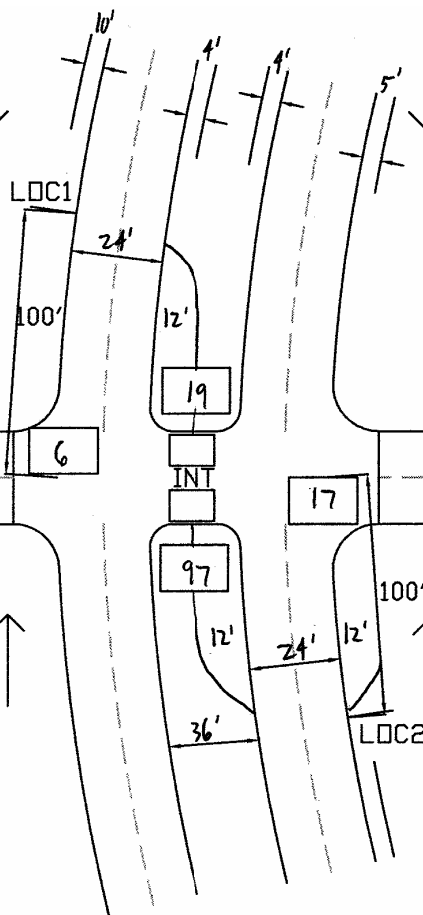
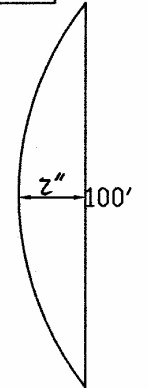
GAP (s)	
t1	t2
27.99	29.11
29.02	31.33
28.31	29.65
27.43	32.18
29.27	30.30
26.76	31.17
27.18	31.29
27.63	30.08
26.54	29.52
27.73	30.67

GAP (s)	
t1	t2
10.37	10.39
11.19	10.67
10.73	11.03
10.10	10.54
10.21	10.08
10.18	9.97
11.54	10.88
10.41	12.04
9.74	10.02
10.23	10.50

COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
13.65	
14.27	
12.76	
13.03	
13.68	
13.27	
12.71	
13.99	
14.20	
12.99	



DATE: 07/02/03
 TIME: 10:30 AM
 WEATHER: Clear
 DISTRICT: Vincennes
 COUNTY: Daviness
 OBSERVER: PS
 MAJOR ROAD: US-50/150
 MINOR ROAD: CR300W/Maysville Rd.
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: Crest

Figure A-25 Intersection of US-50/150 & SR-257 (Davies County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	3.2	3.4	3.2	3.6
LOC1	3.0	3.5	2.4	2.9
LOC2	3.2	3.6	3.7	3.3

COUNTS (veh):
 PERIOD (min):

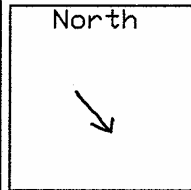
GAP (s)	
t1	t2
4.54	4.41
4.11	4.20
4.53	4.08
4.42	4.31
4.57	4.30

GAP (s)	
t1	t2
21.38	
23.18	
22.83	
24.20	
24.01	
23.48	
23.63	
24.04	
23.40	
23.28	

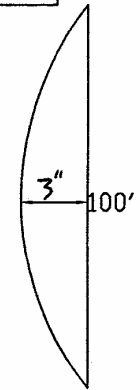
GAP (s)	
t1	t2
22.95	24.38
20.58	25.68
21.92	24.67
23.26	24.52
21.42	25.30
22.55	24.09
22.65	25.12
22.03	24.40
20.21	24.59
21.27	24.39

GAP (s)	
t1	t2
23.27	22.63
23.94	21.08
20.23	20.27
21.59	21.50
23.03	22.88
24.28	21.76
21.22	21.62
21.91	21.81
24.77	22.47
20.86	21.55

COUNTS (veh):
 PERIOD (min):



GAP (s)	
t1	t2
14.25	
13.52	
14.12	
14.86	
14.66	
15.27	
15.92	
14.20	
14.23	
15.42	



DATE: 07/02/03
 TIME: 9:00 AM
 WEATHER: Clear
 DISTRICT: Vincennes
 COUNTY: Davies
 OBSERVER: PS
 MAJOR ROAD: US-50/150
 MINOR ROAD: SR-257
 SPEED LIMIT: 55
 CONTROL: TWFL w/ flashers
 VERTICAL CURVE: No

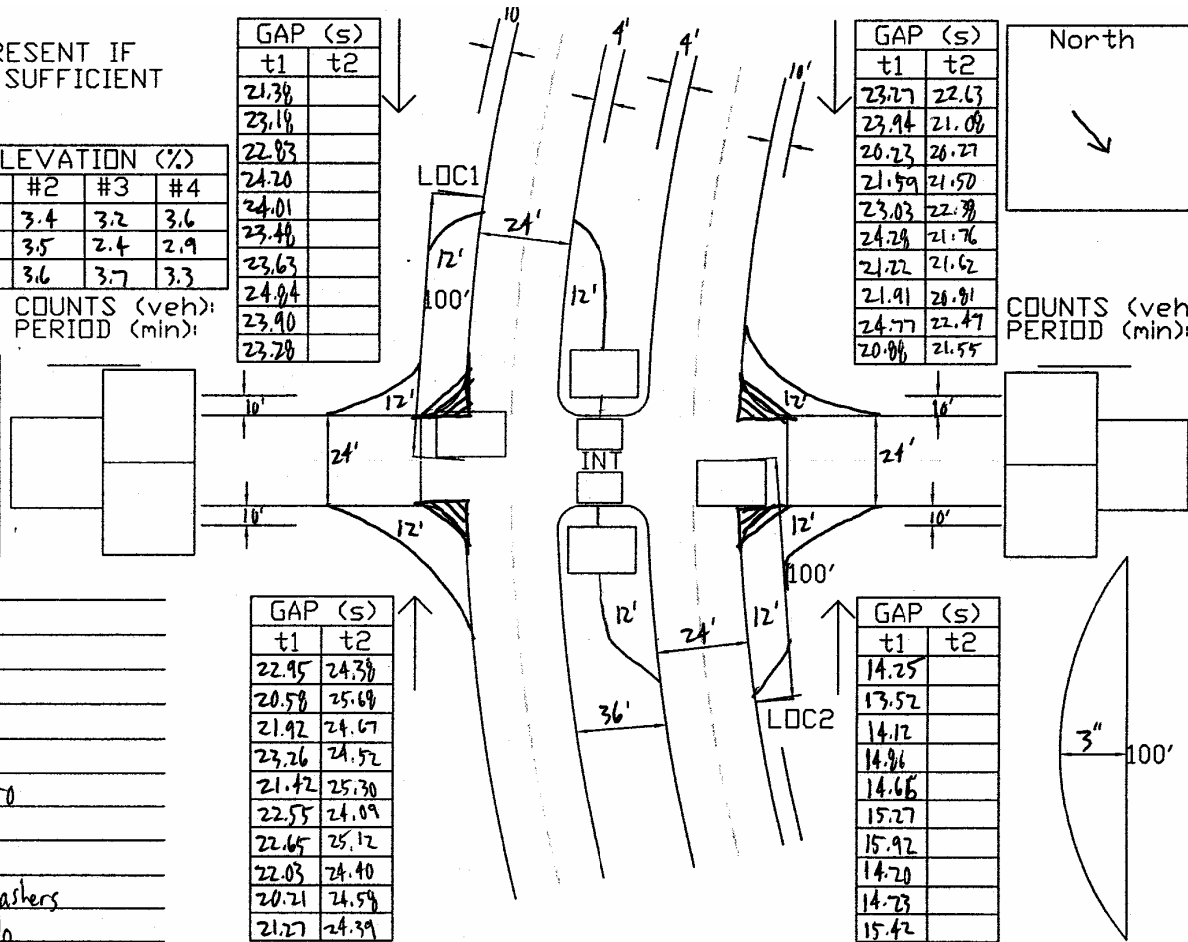


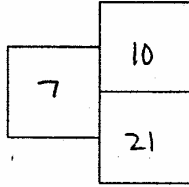
Figure A-26 Intersection of US-41 & CR1025S (Gibson County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	2.2	4.3	2.5	2.8
LOC1	2.1	4.4	2.4	3.6
LOC2	2.1	4.6	2.3	2.7

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.21	4.38
4.60	4.21
4.37	4.57
4.25	4.21
4.42	4.36

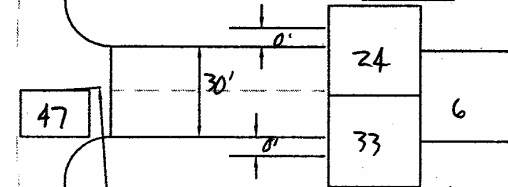


GAP (s)	
t1	t2
20.96	
19.07	
22.17	
21.26	
21.88	
22.99	
22.43	
21.31	
22.14	
19.69	

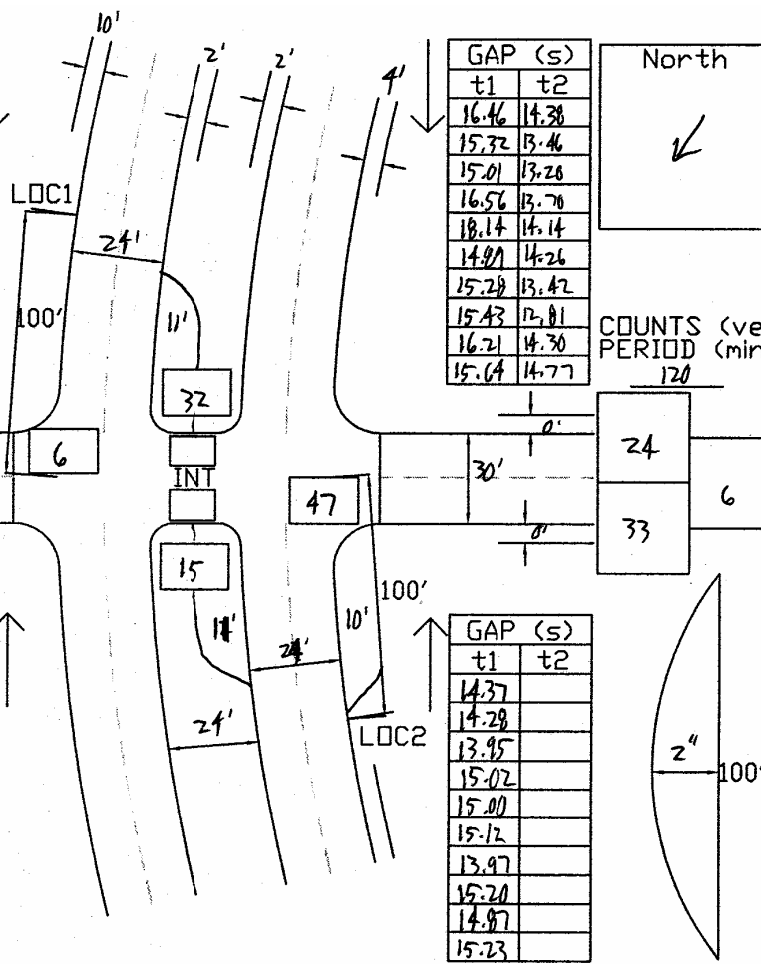
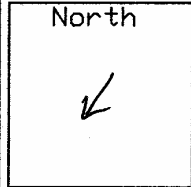
GAP (s)	
t1	t2
18.27	20.16
19.45	21.37
17.91	21.54
17.33	20.78
19.01	21.39
16.22	21.41
18.53	20.57
17.36	20.66
17.77	20.23
16.45	21.81

GAP (s)	
t1	t2
16.46	14.38
15.32	13.46
15.01	13.28
16.56	13.78
18.14	14.14
14.89	14.26
15.28	13.42
15.43	12.81
16.21	14.30
15.64	14.77

COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
14.37	
14.28	
13.95	
15.02	
15.00	
15.12	
13.97	
15.20	
14.87	
15.23	



DATE: 06/11/03
 TIME: 3:30 PM
 WEATHER: Rainy
 DISTRICT: Vincennes
 COUNTY: Gibson
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: CR 1025S
 SPEED LIMIT: 50
 CONTROL: TWSL
 VERTICAL CURVE: No

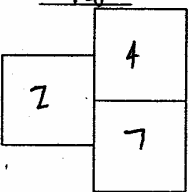
Figure A-27 Intersection of US-41 & CR150S (Gibson County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

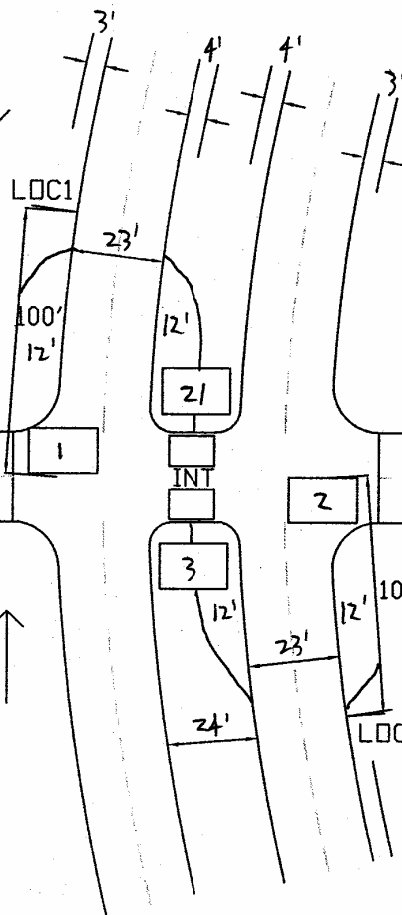
SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	3.2	3.6	2.8	3.2
LOC1	3.2	3.8	3.4	3.6
LOC2	3.8	3.6	3.4	3.3

COUNTS (veh):
 PERIOD (min):
 120

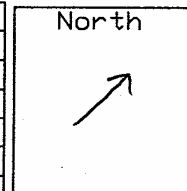
GAP (s)	
t1	t2
4.89	4.56
4.57	4.78
4.69	4.84
4.48	4.86
4.52	4.51



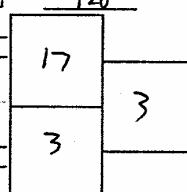
GAP (s)	
t1	t2
20.07	
19.54	
21.10	
20.26	
21.84	
22.19	
20.37	
21.10	
20.85	
20.15	



GAP (s)	
t1	t2
16.70	12.42
15.14	13.27
14.48	13.15
16.25	12.62
16.44	12.21
16.02	13.48
15.82	13.72
15.81	13.58
16.47	14.08
15.74	13.91

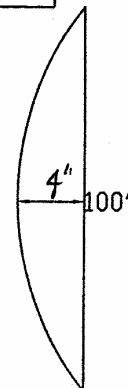


COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
26.37	28.41
26.87	26.14
24.97	26.29
26.47	25.80
22.18	27.77
22.43	26.43
22.74	26.21
26.81	27.48
26.34	28.57
26.86	28.55

GAP (s)	
t1	t2
10.20	
10.11	
9.29	
9.69	
16.08	
10.58	
9.89	
9.75	
8.96	
9.67	



DATE: 06/11/03
 TIME: 1:30 PM
 WEATHER: Rainy
 DISTRICT: Vincennes
 COUNTY: Gibson
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: CR 150S
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: N0

Figure A-28 Intersection of US-41 & CR350N (Gibson County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	0.8	2.3	1.6	2.4
LOC1	1.6	1.7	1.5	2.3
LOC2	1.6	3.2	2.1	2.9

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.30	4.35
4.30	4.11
4.30	4.37
4.45	4.57
4.47	4.74

GAP (s)	
t1	t2
28.84	
23.10	
25.05	
25.62	
24.56	
24.11	
23.35	
27.15	
24.36	
24.55	

GAP (s)	
t1	t2
23.03	21.30
24.80	22.42
25.31	22.37
24.57	21.69
24.44	22.35
25.26	21.39
24.04	21.46
23.46	20.79
23.58	22.08
25.65	21.40

COUNTS (veh):
 PERIOD (min):

DATE: 06/14/03
 TIME: 9:00 AM
 WEATHER: cloudy
 DISTRICT: Vincennes
 COUNTY: Gibson
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: CR350N/Grave St.
 SPEED LIMIT: 55
 CONTROL: TWISL
 VERTICAL CURVE: No

GAP (s)	
t1	t2
12.36	15.96
13.55	16.41
12.69	17.11
13.26	16.60
12.48	16.43
13.31	17.28
14.26	15.72
13.19	16.15
13.85	16.29
14.17	16.72

GAP (s)	
t1	t2
9.85	
9.16	
10.23	
9.37	
10.47	
10.25	
10.53	
10.3	
10.69	
9.42	

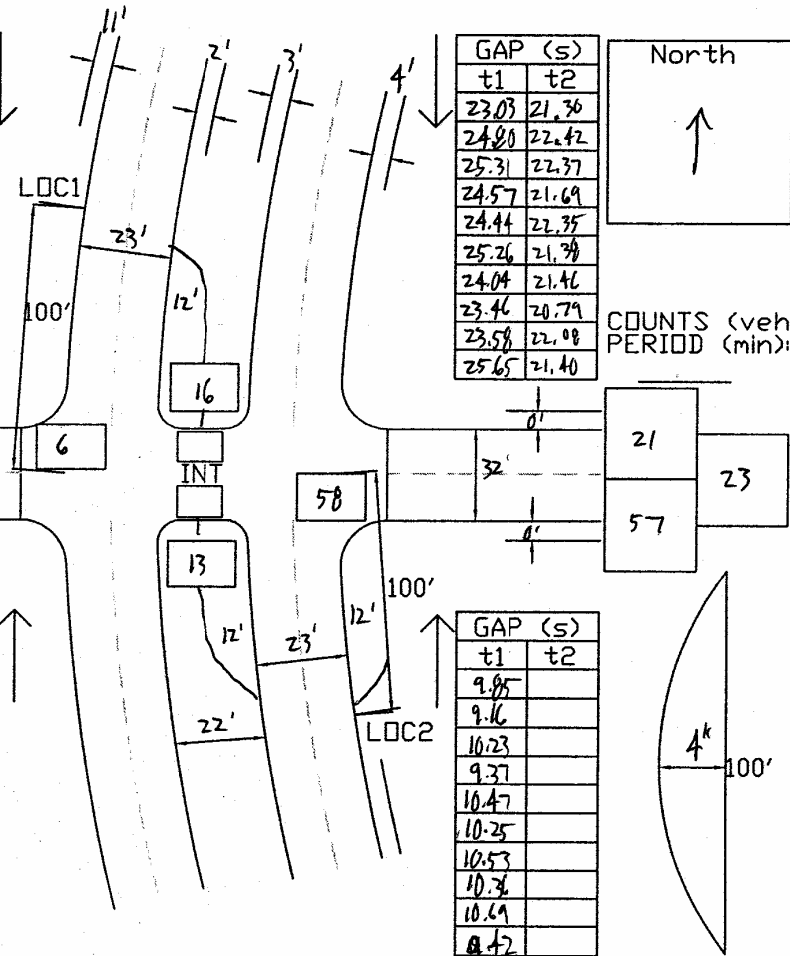


Figure A-29 Intersection of US-41 & SR-56 (Gibson County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

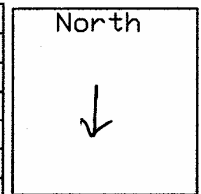
SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	0.5	0.9	0.6	1.3
LOC1	1.0	0.8	0.6	1.0
LOC2	0.7	1.1	1.1	0.7

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.90	
4.48	
4.63	
4.52	
4.58	

GAP (s)	
t1	t2
29.20	
31.20	
34.95	
32.83	
29.32	
35.13	
32.54	
30.78	
34.60	
32.20	

GAP (s)	
t1	t2
29.20	
31.20	
34.95	
32.83	
29.32	
35.13	
32.54	
30.78	
34.60	
32.20	



COUNTS (veh):
 PERIOD (min):

DATE: 07/14/03
 TIME: 11:00 AM
 WEATHER: Clear
 DISTRICT: Vincennes
 COUNTY: Gibson
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: SR-56
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

GAP (s)	
t1	t2
20.45	21.46
22.12	21.29
20.29	22.38
21.18	20.68
21.03	20.77
21.20	21.28
20.82	20.27
21.39	21.39
22.40	22.66
19.89	20.95

GAP (s)	
t1	t2
20.45	
22.12	
20.29	
21.18	
21.03	
21.20	
20.82	
21.39	
22.40	
19.89	

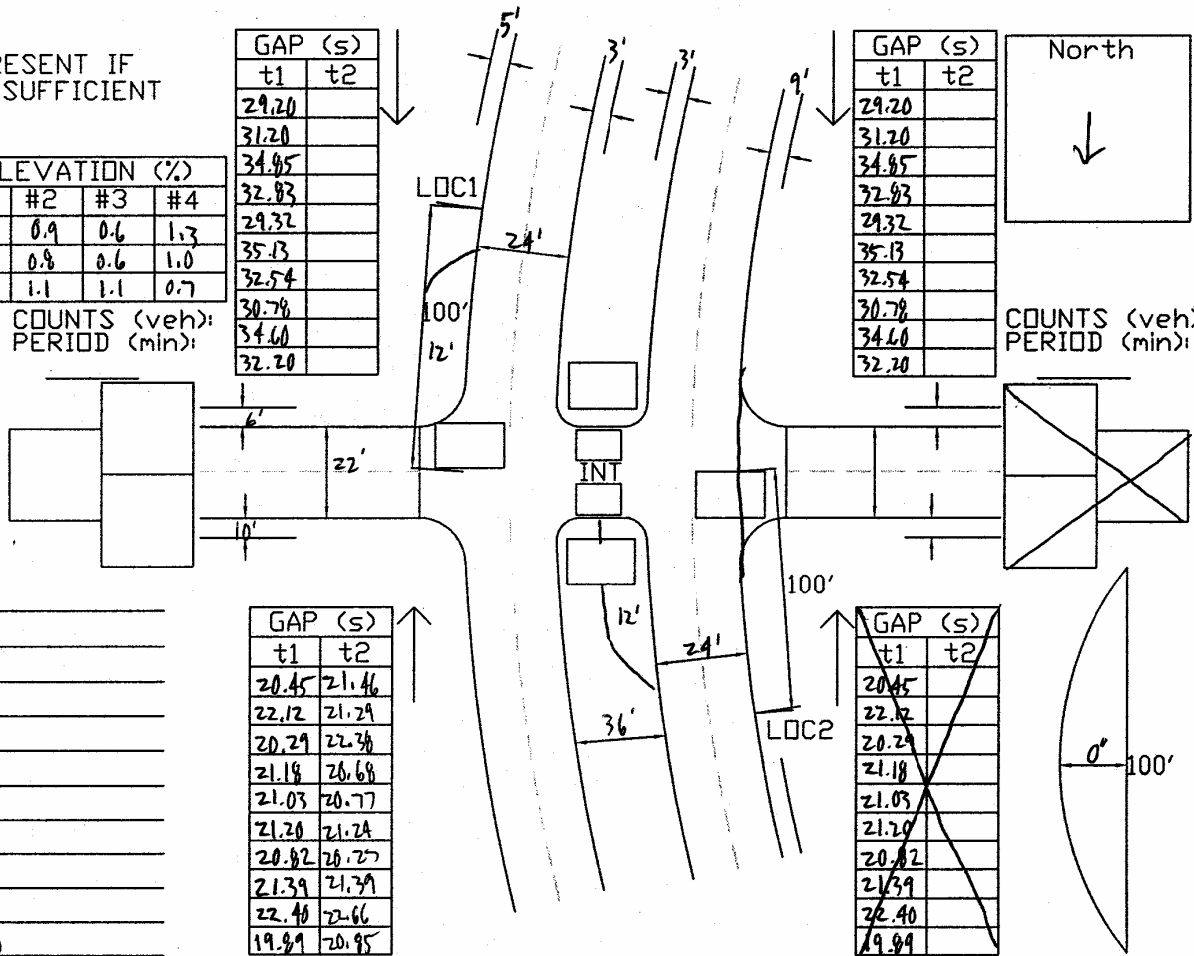


Figure A-30 Intersection of US-41 & Old US-41 (Gibson County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	0.6	0.7	1.1	0.7
LOC1	0.5	1.7	2.2	0.7
LOC2	1.5	0.2	0.7	1.4

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.72	4.78
4.66	4.64
4.89	4.82
4.60	4.77
4.79	4.51

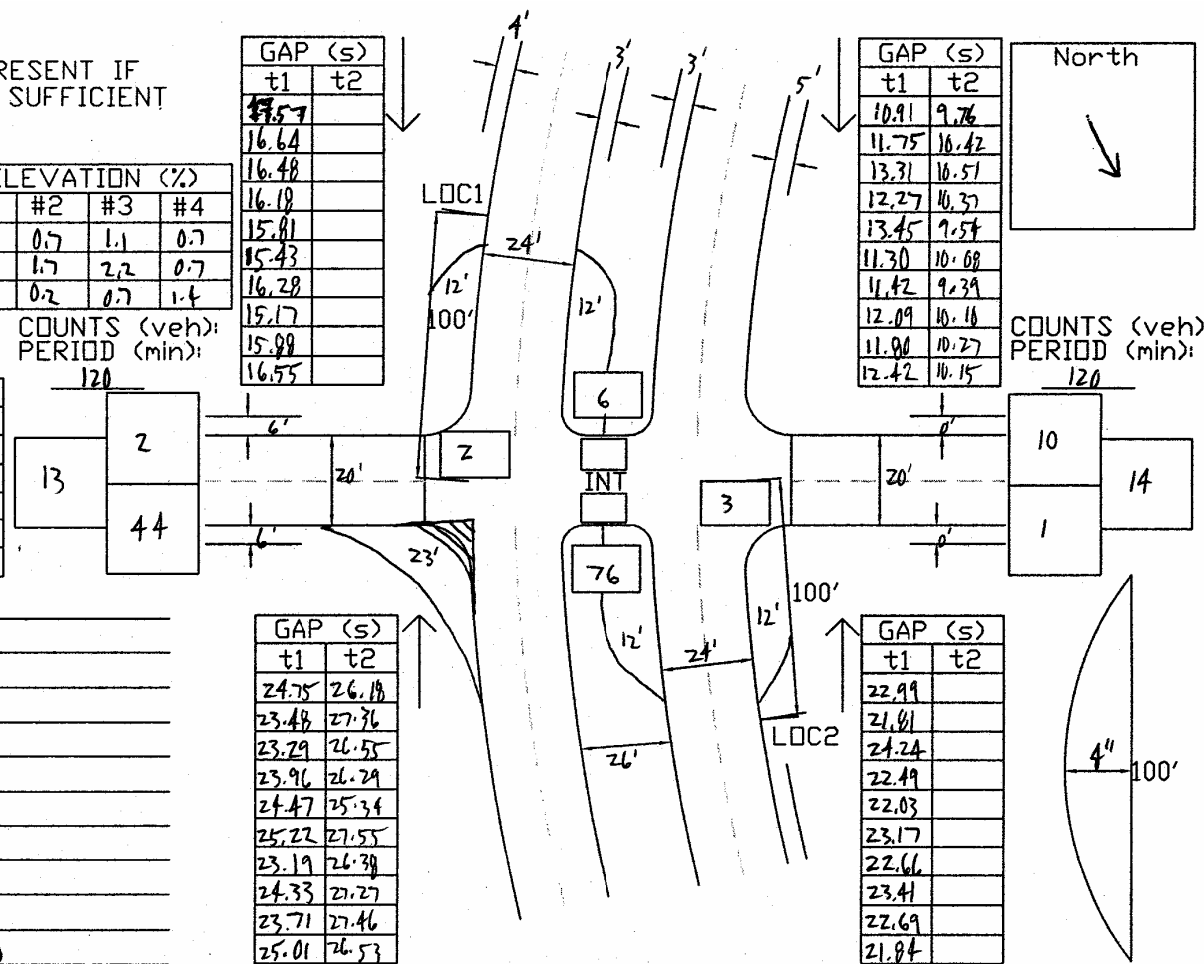
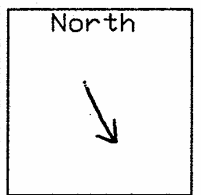
GAP (s)	
t1	t2
17.57	
16.64	
16.48	
16.18	
15.81	
15.43	
16.28	
15.17	
15.88	
16.55	

GAP (s)	
t1	t2
24.75	26.18
23.48	27.76
23.29	26.55
23.96	26.29
24.47	25.34
25.22	27.55
23.19	26.38
24.33	27.27
23.71	27.46
25.01	26.53

GAP (s)	
t1	t2
10.91	9.76
11.75	10.42
13.31	10.51
12.27	10.37
13.45	9.54
11.30	10.68
11.42	9.39
12.09	10.16
11.90	10.27
12.42	10.15

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
22.99	
21.81	
24.24	
22.49	
22.03	
23.17	
22.66	
23.41	
22.69	
21.84	



DATE: 07/14/03
 TIME: 9:00 AM
 WEATHER: Clear
 DISTRICT: Vinennes
 COUNTY: Gibson
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: Old US-41
 SPEED LIMIT: 55
 CONTROL: TWSL
 VERTICAL CURVE: No

Figure A-31 Intersection of US-41 & CR575N (Gibson County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	1.7	0.5	1.5	1.4
LOC1	1.2	0.4	0.5	1.1
LOC2	1.3	0.5	0.5	0.9

COUNTS (veh):
 PERIOD (min):

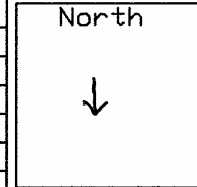
GAP (s)	
t1	t2
4.64	4.48
4.70	4.39
4.76	4.31
4.49	4.41
4.46	4.31

GAP (s)	
t1	t2
46.80	
47.86	
46.78	
49.17	
49.58	
49.17	
49.91	
49.90	
46.76	
50.41	

GAP (s)	
t1	t2
19.74	20.06
20.19	20.29
20.42	20.48
20.56	20.47
19.34	21.56
19.33	19.76
21.06	20.18
17.57	20.05
17.74	19.41
17.76	20.38

GAP (s)	
t1	t2
33.10	26.43
35.23	25.87
32.24	25.54
32.12	25.70
33.51	26.52
34.00	25.60
32.05	26.12
33.35	27.39
30.25	26.40
30.93	26.16

COUNTS (veh):
 PERIOD (min):



DATE: 06/14/03
 TIME: 11:00 AM
 WEATHER: Cloudy
 DISTRICT: Vincennes
 COUNTY: Gibson
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: CR575N
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

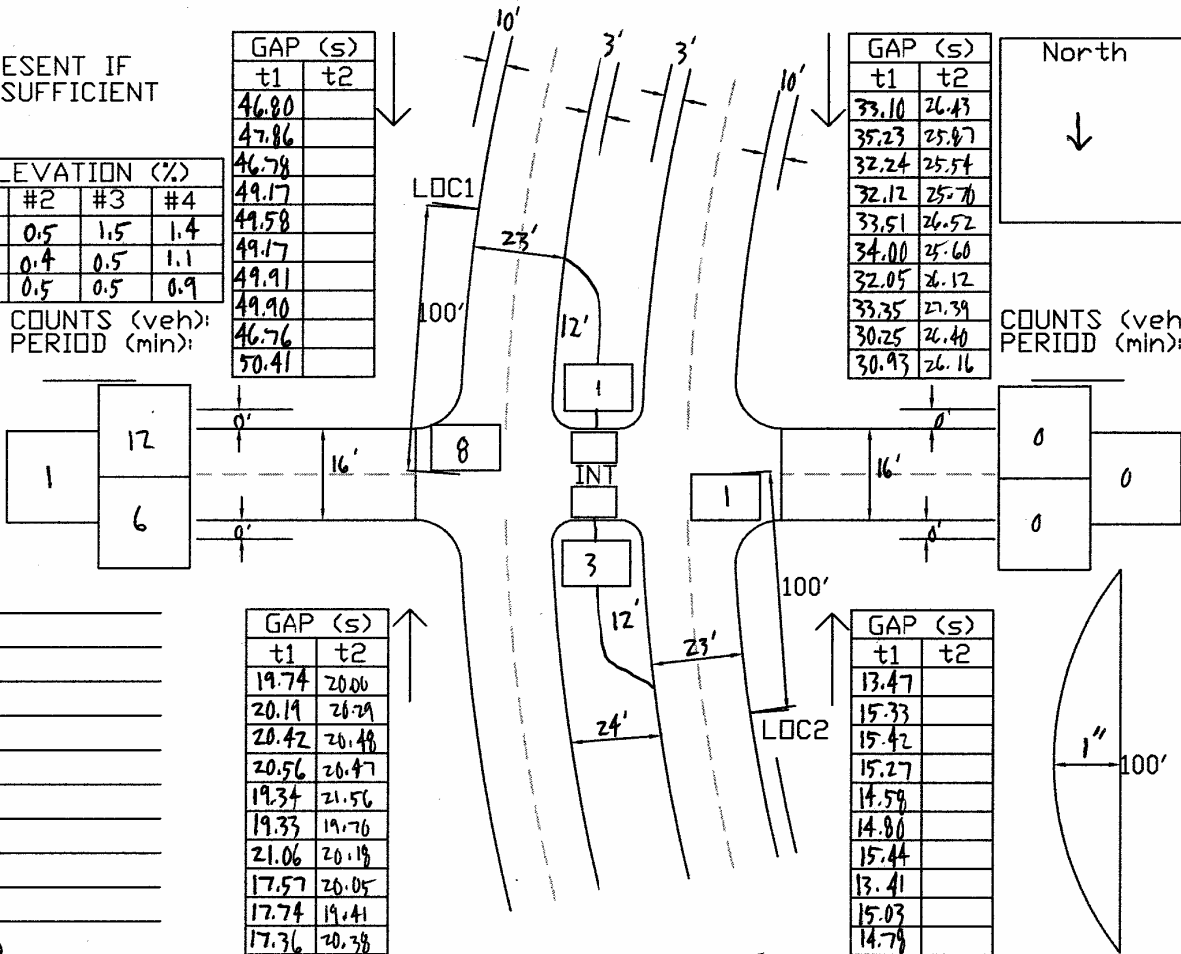


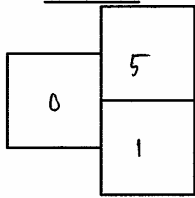
Figure A-32 Intersection of US-41 & CR550W (Knox County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

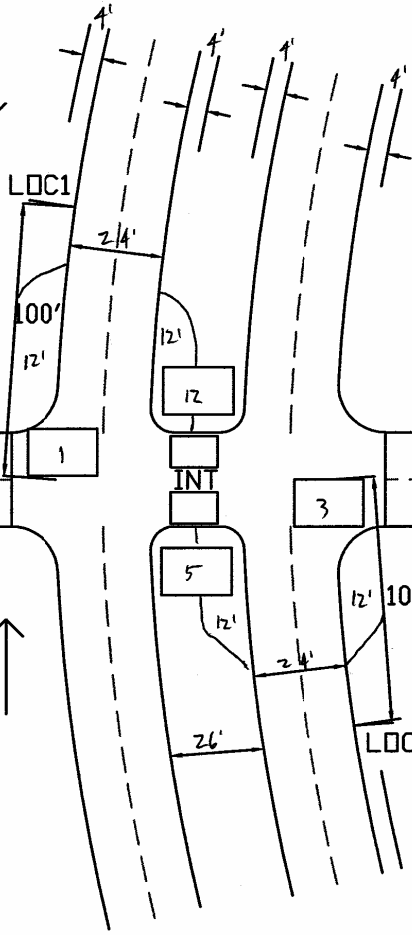
SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	4.2	3.9	4.0	4.7
LOC1	3.9	4.5	3.4	4.4
LOC2	3.9	4.8	4.3	4.5

COUNTS (veh):
 PERIOD (min):
 12.0

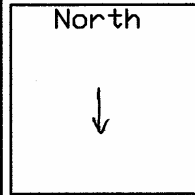
GAP (s)	
t1	t2
4.66	5.16
4.57	5.07
5.16	5.07
5.24	4.93
5.19	4.86



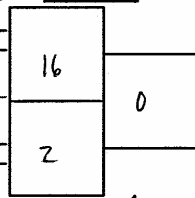
GAP (s)	
t1	t2
26.22	
27.80	
28.49	
27.18	
29.34	
28.74	
28.72	
30.64	
29.65	
30.10	



GAP (s)	
t1	t2
24.18	24.14
25.62	23.26
27.02	24.07
25.92	24.39
26.62	23.27
26.31	23.46
26.95	23.69
26.78	22.91
24.35	23.08
25.47	22.14

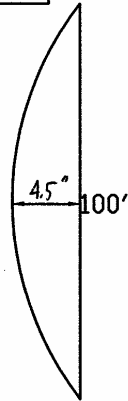


COUNTS (veh):
 PERIOD (min):
 12.0



GAP (s)	
t1	t2
31.66	32.26
28.61	31.14
31.46	30.53
29.37	31.08
31.65	30.29
28.98	29.40
27.34	29.36
32.32	30.70
30.69	31.81
29.55	30.22

GAP (s)	
t1	t2
25.00	
31.13	
32.56	
31.08	
27.46	
30.68	
29.06	
30.61	
27.11	
27.21	



DATE: 07/14/03
 TIME: 11:45 AM
 WEATHER: Clear
 DISTRICT: Winkennes
 COUNTY: Knox
 OBSERVER: ps
 MAJOR ROAD: US-41
 MINOR ROAD: Hazelton Rd./McLeary Rd. (CR550W)
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

Figure A-33 Intersection of US-41 & SR-241 (Knox County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	6.1	6.6	7.2	5.9
LOC1	6.4	6.4	6.3	6.5
LOC2	6.1	6.7	6.3	6.8

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
5.30	
5.19	
4.81	
4.75	
4.88	

GAP (s)	
t1	t2
17.01	
17.06	
16.15	
16.31	
16.18	
15.84	
17.87	
18.17	
15.77	
18.11	

GAP (s)	
t1	t2
15.27	
14.43	
13.78	
14.59	
16.00	
14.33	
15.48	
14.66	
15.79	
15.20	

COUNTS (veh):
 PERIOD (min):

DATE: 07/01/03
 TIME: 1:45 PM
 WEATHER: Rainy
 DISTRICT: Vincennes
 COUNTY: Knox
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: US-241
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: N₀

GAP (s)	
t1	t2
14.73	20.80
14.93	21.12
16.20	19.13
15.69	20.31
16.20	20.52
15.97	21.60
16.79	19.89
16.81	20.07
16.64	20.41
14.78	19.62

GAP (s)	
t1	t2

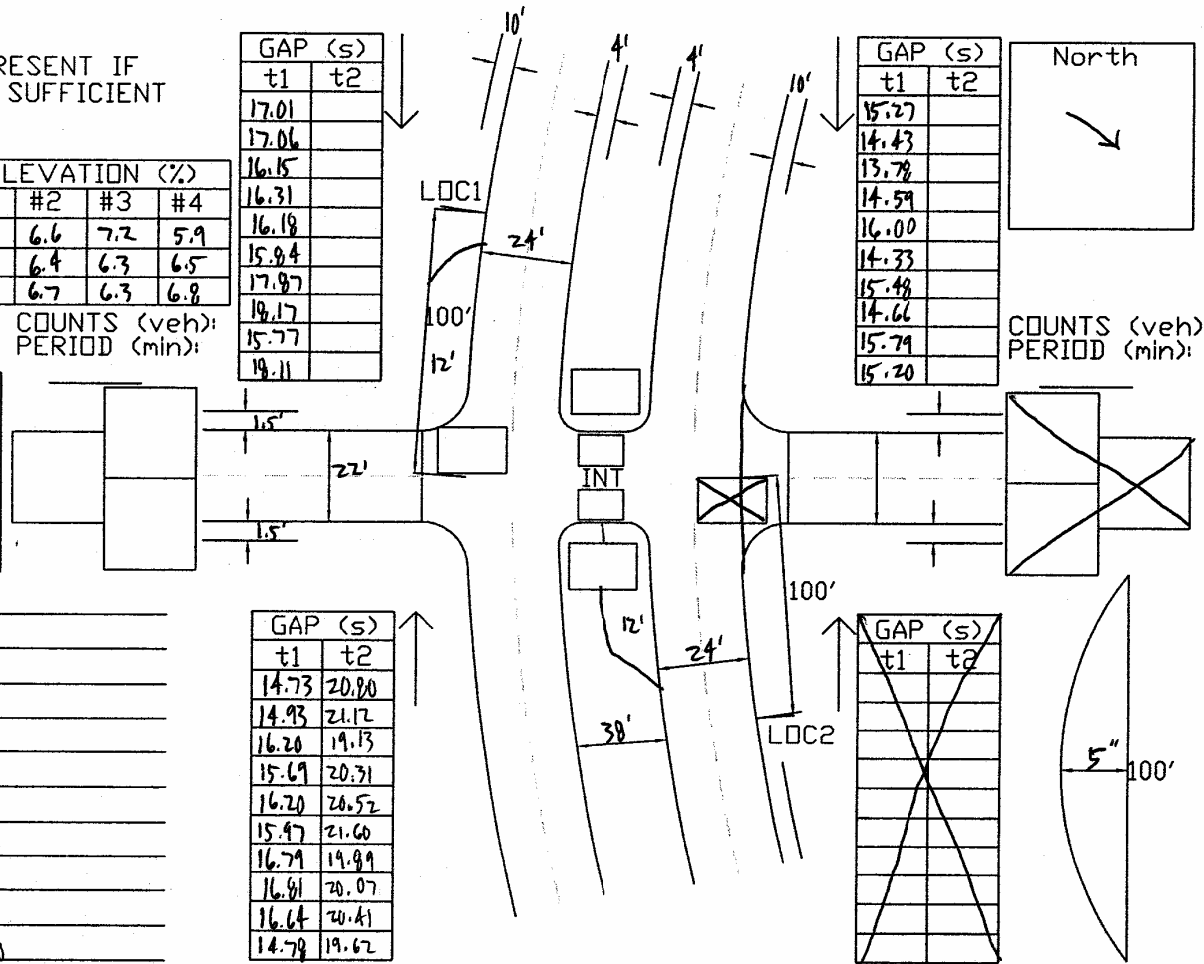


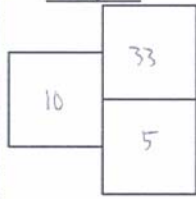
Figure A-34 Intersection of US-41 & CR500W (Knox County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	0.9	2.5	1.1	1.4
LOC1	1.4	2.3	1.2	1.4
LOC2	3.2	3.7	3.9	3.9

COUNTS (veh):
 PERIOD (min):
 120

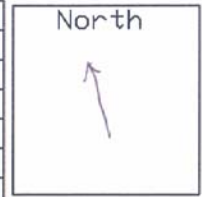
GAP (s)	
t1	t2
4.44	4.64
4.30	4.74
4.44	4.41
4.47	4.66
4.50	4.83



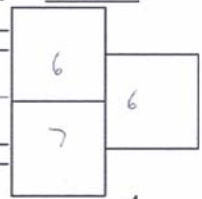
GAP (s)	
t1	t2
49.43	
49.16	
50.39	
50.77	
52.45	
52.09	
53.20	
51.96	
53.05	
49.50	



GAP (s)	
t1	t2
44.49	42.41
41.67	41.60
43.48	43.21
44.84	40.72
44.85	40.67
45.11	41.02
44.96	39.78
43.46	40.61
46.16	41.42
46.50	41.58

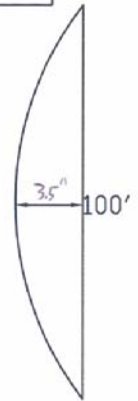


COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
27.99	28.40
27.52	27.92
27.24	29.29
26.79	28.16
28.61	28.66
25.11	30.89
23.71	27.37
24.80	28.81
25.20	28.40
24.16	27.27

GAP (s)	
t1	t2
22.41	
21.97	
19.72	
22.39	
22.61	
22.20	
24.58	
21.22	
20.51	
20.24	



DATE: 07/01/03
 TIME: 11:00 AM
 WEATHER: Cloudy
 DISTRICT: Virgenes
 COUNTY: Knox
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: St. Thomas Rd/Essex Rd. (CR500W)
 SPEED LIMIT: 55
 CONTROL: TW56
 VERTICAL CURVE: No

Figure A-35 Intersection of US-41 & CR1000N (Knox County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

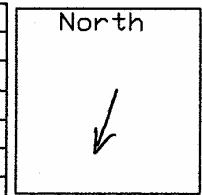
SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	4.6	5.6	5.0	5.2
LOC1	5.3	5.4	5.1	5.7
LOC2	5.2	5.7	5.5	5.7

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.75	4.76
4.81	4.94
5.14	5.20
5.08	5.28
5.04	5.10

GAP (s)	
t1	t2
18.37	
18.12	
18.07	
18.47	
19.28	
17.60	
16.90	
18.87	
18.64	
17.28	

GAP (s)	
t1	t2
14.51	11.56
14.69	10.62
13.68	12.07
13.83	11.42
13.12	11.49
13.66	11.14
14.62	12.29
14.29	10.38
14.83	11.51
14.48	11.92



COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
16.21	19.26
16.09	18.49
16.26	20.02
15.14	20.18
15.10	19.37
16.22	19.35
16.19	19.60
16.62	20.71
16.92	18.48
15.55	19.06

GAP (s)	
t1	t2
11.63	
12.04	
12.63	
11.62	
11.45	
11.37	
12.41	
12.18	
11.48	
12.05	

DATE: 07/03/03
 TIME: 7:00 AM
 WEATHER: Cloudy
 DISTRICT: Viennes
 COUNTY: Knox
 OBSERVER: ps
 MAJOR ROAD: US-41
 MINOR ROAD: Freelandville Rd./CR1000N
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

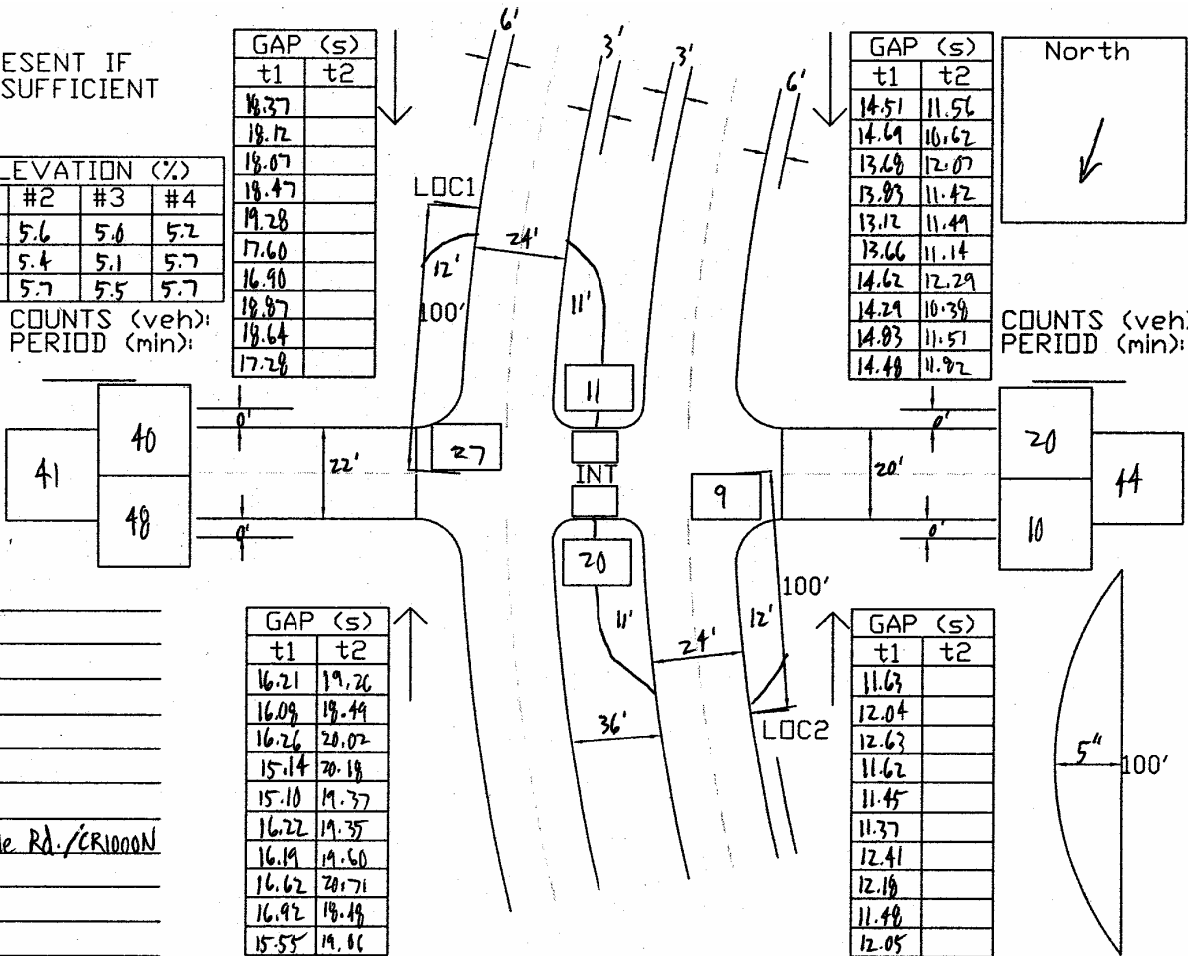


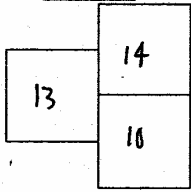
Figure A-36 Intersection of US-41 & CR1100NE (Knox County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	0.9	2.5	0.1	1.8
LOC1	0.1	1.8	1.2	1.6
LOC2	2.7	4.2	2.3	3.9

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.97	5.27
4.99	5.36
5.22	4.88
5.16	5.10
4.96	4.93

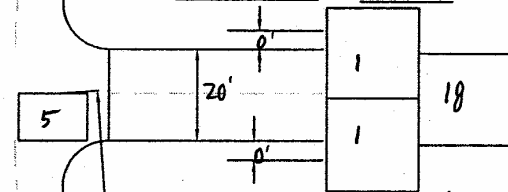


GAP (s)	
t1	t2
23.63	
24.32	
22.83	
22.28	
22.14	
20.19	
19.82	
20.62	
20.80	
19.78	

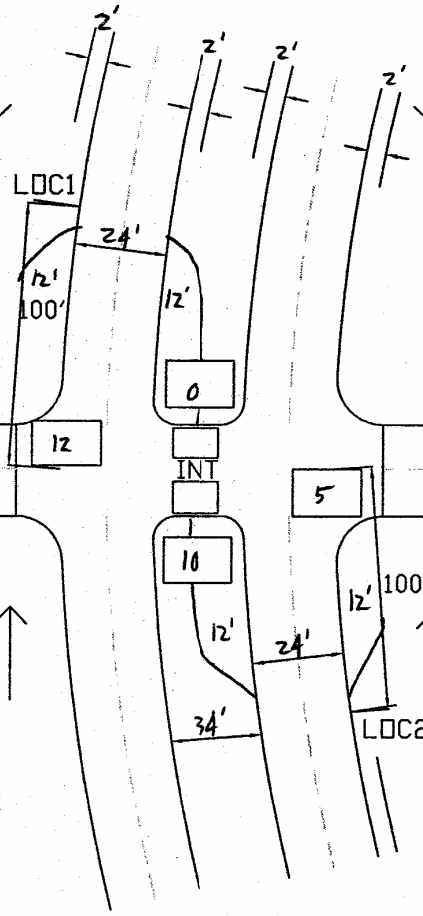
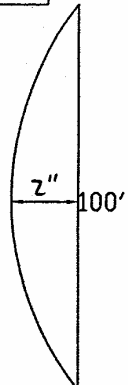
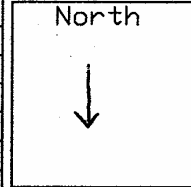
GAP (s)	
t1	t2
20.95	23.11
20.91	24.38
20.39	24.62
21.77	24.88
21.58	23.40
21.83	24.29
23.14	23.60
22.75	23.47
21.70	24.51
21.36	24.30

GAP (s)	
t1	t2
20.20	17.99
20.21	18.26
21.60	18.31
19.41	18.54
21.72	17.38
20.45	17.27
22.14	18.57
19.11	17.88
20.41	17.79
21.01	18.26

COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
14.50	
14.82	
14.00	
13.80	
13.42	
14.22	
13.32	
14.08	
14.54	
13.75	



DATE: 07/14/03
 TIME: 3:00 PM
 WEATHER: Cloudy
 DISTRICT: Vincennes
 COUNTY: Knox
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: CR1100NE
 SPEED LIMIT: 55
 CONTROL: TWSL
 VERTICAL CURVE: No

Figure A-37 Intersection of US-41 & SR550 (Knox County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	2.0	1.3	2.0	0.5
LOC1	1.1	2.3	2.1	1.5
LOC2	0.9	2.1	2.3	1.0

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.87	5.01
4.72	4.79
4.96	4.62
4.86	4.99
4.75	4.82

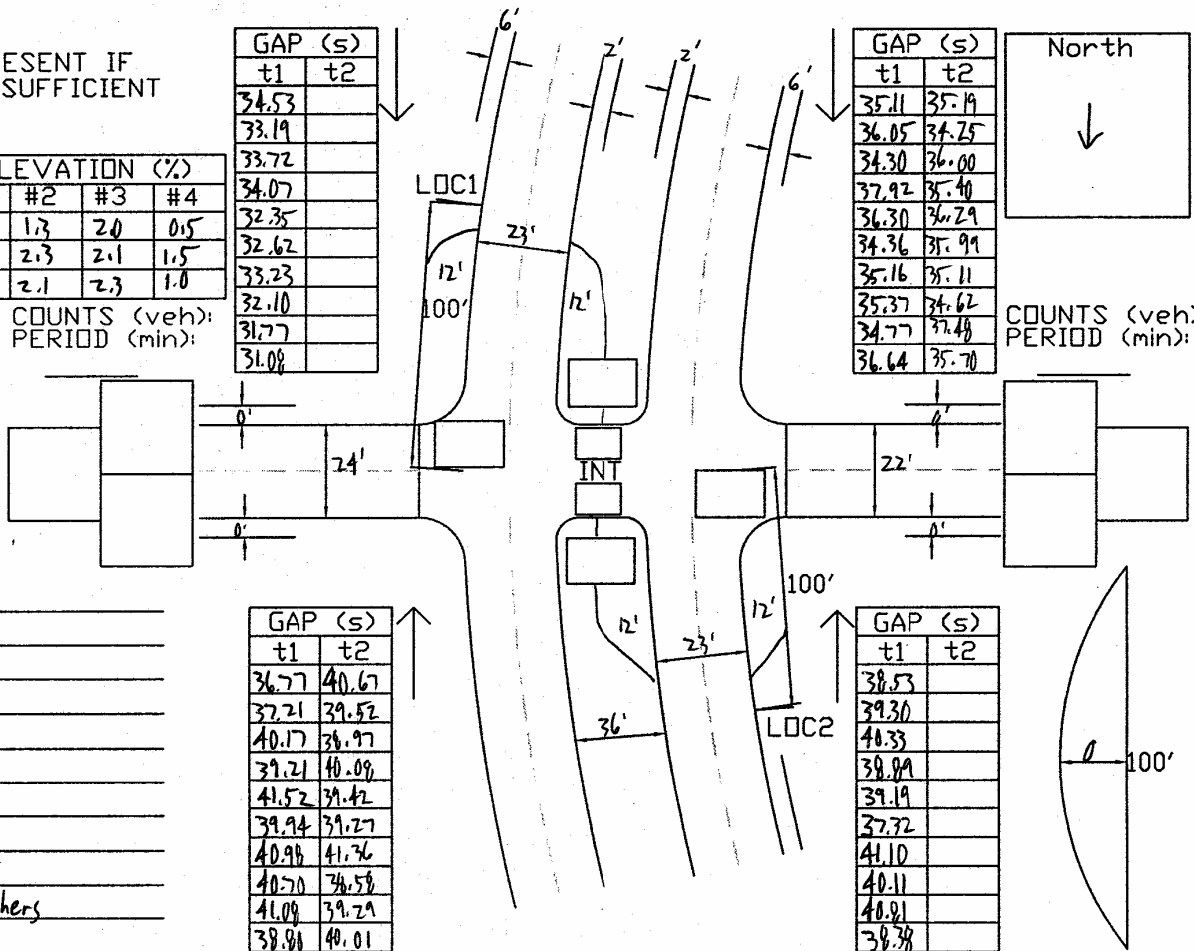
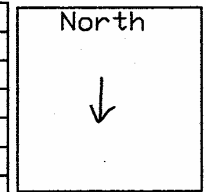
GAP (s)	
t1	t2
34.53	
33.19	
33.72	
34.07	
32.35	
32.62	
33.23	
32.10	
31.77	
31.08	

GAP (s)	
t1	t2
36.77	40.67
37.21	39.52
40.17	38.97
39.21	40.08
41.52	39.42
39.94	39.27
40.96	41.76
40.70	38.58
41.08	39.29
38.88	40.01

GAP (s)	
t1	t2
35.11	35.19
36.05	34.25
34.30	36.00
37.92	35.40
36.30	36.29
34.36	35.99
35.16	35.11
35.37	34.62
34.77	37.48
36.64	35.70

COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
38.53	
39.30	
40.33	
38.89	
39.19	
37.72	
41.10	
40.11	
40.81	
38.38	



DATE: 07/14/03
 TIME: 5:00 PM
 WEATHER: Cloudy
 DISTRICT: Vincennes
 COUNTY: Knox
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: SR-550
 SPEED LIMIT: 55
 CONTROL: TWSC w/Flashers
 VERTICAL CURVE: No

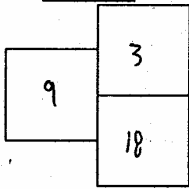
Figure A-38 Intersection of US-50/150 & CRSE500E (Benton County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

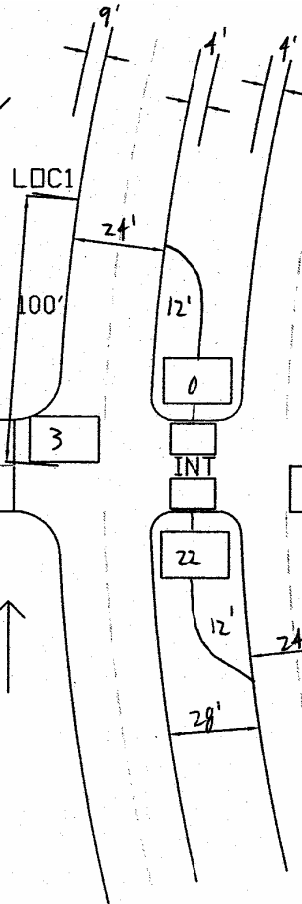
SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	1.0	0.9	0.1	1.1
LOC1	1.4	1.7	0.1	1.3
LOC2	1.2	0.7	1.1	0.0

COUNTS (veh):
 PERIOD (min):
 124

GAP (s)	
t1	t2
4.49	4.30
4.51	4.40
4.45	4.36
4.51	4.35
4.29	4.47

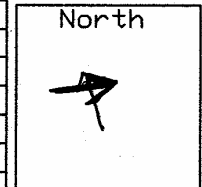


GAP (s)	
t1	t2
10.85	
11.15	
10.92	
10.70	
10.26	
12.03	
9.61	
10.81	
10.08	
11.96	

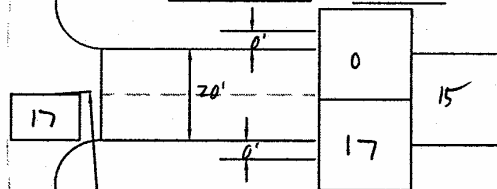


GAP (s)	
t1	t2
23.60	23.85
21.99	25.81
23.17	22.77
23.70	23.29
23.11	22.14
24.56	24.46
22.24	24.63
23.54	23.77
24.54	23.18
23.24	24.28

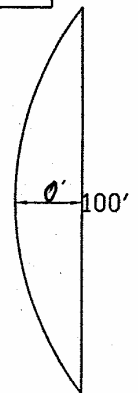
GAP (s)	
t1	t2
9.62	10.66
10.75	10.54
10.06	10.36
10.23	9.76
10.51	10.41
10.22	10.77
10.51	10.38
9.32	9.56
9.52	10.29
10.94	10.14



COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
24.68	
25.73	
25.50	
25.49	
24.07	
27.61	
25.75	
25.11	
27.07	
26.88	



DATE: 07/15/03
 TIME: 1:00 AM
 WEATHER: Cloudy
 DISTRICT: Vincennes
 COUNTY: Knox
 OBSERVER: PS
 MAJOR ROAD: US-50/150
 MINOR ROAD: SE 500E / Anson Rd.
 SPEED LIMIT: 55
 CONTROL: TWSL
 VERTICAL CURVE: No

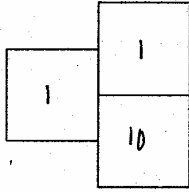
Figure A-39 Intersection of US-50/150 & CRSE900E (Knox County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

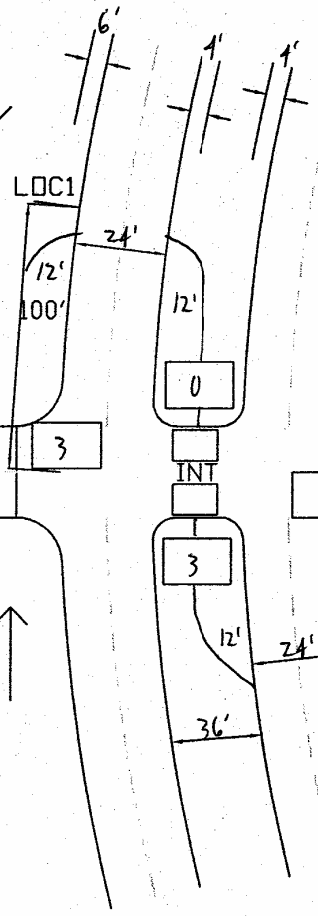
SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	1.3	1.5	2.1	1.6
LOC1	1.5	2.0	2.2	1.6
LOC2	1.8	1.9	2.0	1.6

COUNTS (veh):
 PERIOD (min):
 120

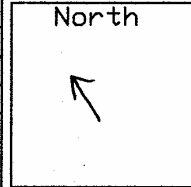
GAP (s)	
t1	t2
4.68	4.78
4.93	4.54
4.68	4.86
4.87	4.60
4.82	4.77



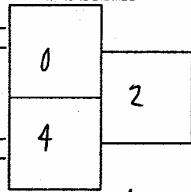
GAP (s)	
t1	t2
37.44	
42.52	
42.80	
42.83	
41.73	
38.83	
40.06	
38.02	
42.36	
40.84	



GAP (s)	
t1	t2
37.60	36.42
37.23	35.58
39.59	35.27
36.84	37.66
37.71	36.39
38.38	36.62
39.56	38.16
37.55	37.32
41.19	36.59
41.10	38.30

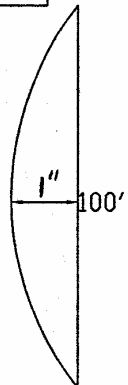


COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
31.42	33.91
30.34	31.92
32.42	32.60
32.66	33.75
31.06	33.88
33.55	32.25
32.59	32.25
30.11	31.09
32.28	32.52
31.15	33.70

GAP (s)	
t1	t2
24.73	
21.96	
22.66	
24.43	
25.48	
24.82	
25.05	
24.27	
24.85	
25.73	



DATE: 07/15/03
 TIME: 11:00 AM
 WEATHER: Rainy
 DISTRICT: Vincennes
 COUNTY: Knox
 OBSERVER: PS
 MAJOR ROAD: US-50/150
 MINOR ROAD: SE900E/Strawberry Hill Rd.
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

Figure A-40 Intersection of SR-37 & SR-54/58 (Lawrence County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	6.4	7.6	7.5	7.2
LOC1	7.3	7.7	7.7	7.3
LOC2	7.8	7.5	6.1	6.7

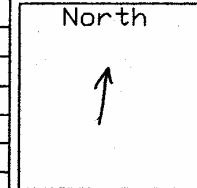
COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.10	
4.12	
4.17	
4.20	
4.03	

GAP (s)	
t1	t2
16.01	
17.08	
16.27	
16.04	
17.44	
15.33	
14.94	
15.51	
17.17	
15.04	

GAP (s)	
t1	t2
13.16	
12.74	
12.72	
12.31	
12.48	
13.84	
12.89	
13.68	
12.18	
13.40	

COUNTS (veh):
 PERIOD (min):



DATE: 07/15/03
 TIME: 2:00 PM
 WEATHER: Cloudy
 DISTRICT: Vincennes
 COUNTY: Lawrence
 OBSERVER: PS
 MAJOR ROAD: SR-37
 MINOR ROAD: SR-54/58
 SPEED LIMIT: 55
 CONTROL: TWSC w/flashers
 VERTICAL CURVE: No

GAP (s)	
t1	t2
10.80	14.80
10.80	13.52
10.42	13.46
10.85	14.96
11.42	14.33
9.95	13.81
11.88	13.07
10.73	13.39
11.02	13.42
10.79	14.49

GAP (s)	
t1	t2

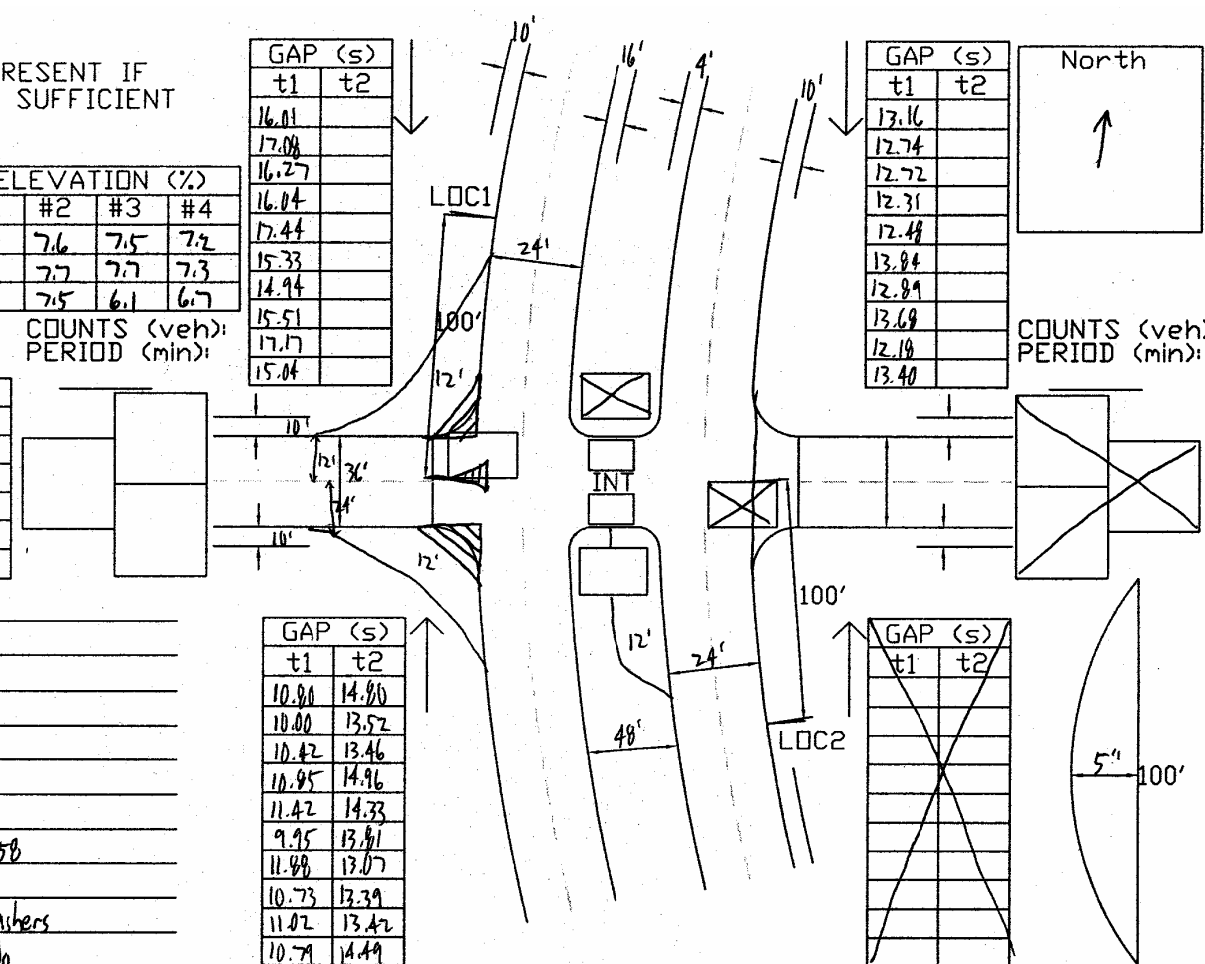
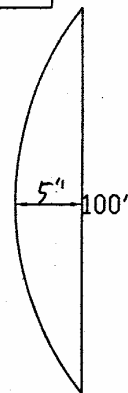


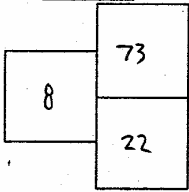
Figure A-41 Intersection of SR-37 & CR475N (Lawrence County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	3.9	4.1	3.4	3.8
LOC1	4.3	4.7	4.0	4.6
LOC2	4.0	4.1	4.0	4.3

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.67	4.63
4.63	4.58
4.72	4.66
4.58	4.72
4.70	4.49

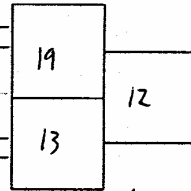


GAP (s)	
t1	t2
9.40	
9.53	
10.11	
10.21	
8.74	
8.49	
9.20	
9.10	
10.22	
9.97	

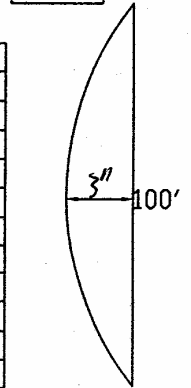
GAP (s)	
t1	t2
15.22	29.62
14.34	30.47
15.56	29.40
15.84	28.26
15.96	29.01
16.65	29.71
15.83	30.50
15.83	29.17
14.45	29.22
15.90	29.90

GAP (s)	
t1	t2
9.88	8.62
9.82	9.42
10.84	9.26
10.59	8.77
9.52	9.52
9.26	9.63
9.79	9.88
10.00	9.90
9.74	8.95
9.94	9.88

COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
10.37	
9.97	
10.54	
9.72	
10.91	
10.88	
10.45	
9.08	
9.93	
9.75	



DATE: 07/15/03
 TIME: 3:30 PM
 WEATHER: Cloudy
 DISTRICT: Vincennes
 COUNTY: Lawrence
 OBSERVER: PS
 MAJOR ROAD: SR-37
 MINOR ROAD: Trogden Lane (CR475N)
 SPEED LIMIT: 55
 CONTROL: TWSL w/Flashers
 VERTICAL CURVE: Crest

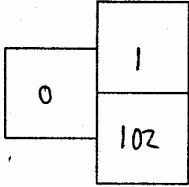
Figure A-42 Intersection of US-41 & CR400S (Sullivan County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	4.2	6.1	2.3	3.0
LOC1	3.6	5.8	2.2	3.0
LOC2	4.3	6.0	2.3	3.8

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.82	4.96
4.91	5.01
4.76	4.84
4.97	4.77
4.62	4.75

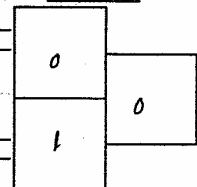


GAP (s)	
t1	t2
44.04	
45.67	
44.38	
52.21	
49.96	
52.12	
52.19	
49.49	
47.08	
44.19	

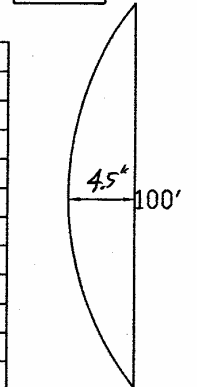
GAP (s)	
t1	t2
15.45	19.47
20.51	20.53
18.64	19.29
19.56	19.86
18.80	18.91
17.85	20.72
19.28	21.57
19.64	19.90
18.85	20.27
20.03	20.60

GAP (s)	
t1	t2
57.35	49.61
52.31	48.42
57.68	48.37
44.18	45.15
50.52	46.80
48.81	44.21
47.95	47.03
52.22	43.62
45.08	48.48
50.52	44.99

COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
16.97	
19.61	
18.24	
18.04	
16.91	
17.11	
17.25	
17.85	
17.68	
17.81	



DATE: 06/09/03
 TIME: 1:15 PM
 WEATHER: Clear
 DISTRICT: Vincennes
 COUNTY: Sullivan
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: CR400S
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

Figure A-43 Intersection of US-41 & CR200N (Sullivan County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	6.7	6.6	5.2	6.2
LOC1	6.4	6.8	5.1	5.9
LOC2	6.4	6.4	5.1	6.2

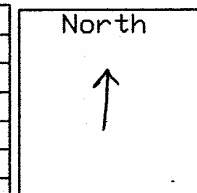
COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.68	4.58
4.92	4.48
5.14	4.82
4.90	4.72
4.76	4.76

GAP (s)	
t1	t2
16.29	
15.11	
14.64	
15.35	
16.05	
17.83	
17.20	
18.01	
17.01	
17.86	

GAP (s)	
t1	t2
11.62	9.60
12.40	10.41
11.70	10.42
12.56	9.77
11.85	11.21
12.66	10.18
12.75	10.68
12.83	9.47
12.99	9.93
12.00	10.23

COUNTS (veh):
 PERIOD (min):



DATE: 06/09/03
 TIME: 11:00 AM
 WEATHER: Clear
 DISTRICT: Vincennes
 COUNTY: Sullivan
 OBSERVER: PS
 MAJOR ROAD: US-41/150
 MINOR ROAD: CR200N/Frakes St.
 SPEED LIMIT: 50
 CONTROL: TWSC
 VERTICAL CURVE: No

GAP (s)	
t1	t2
11.36	14.67
12.73	15.29
13.11	15.54
13.30	14.45
11.05	15.16
10.46	13.37
10.83	13.66
12.25	14.22
12.62	15.08
10.34	14.29

GAP (s)	
t1	t2
8.79	
10.62	
10.44	
8.65	
9.59	
9.18	
8.62	
9.87	
9.08	
10.14	

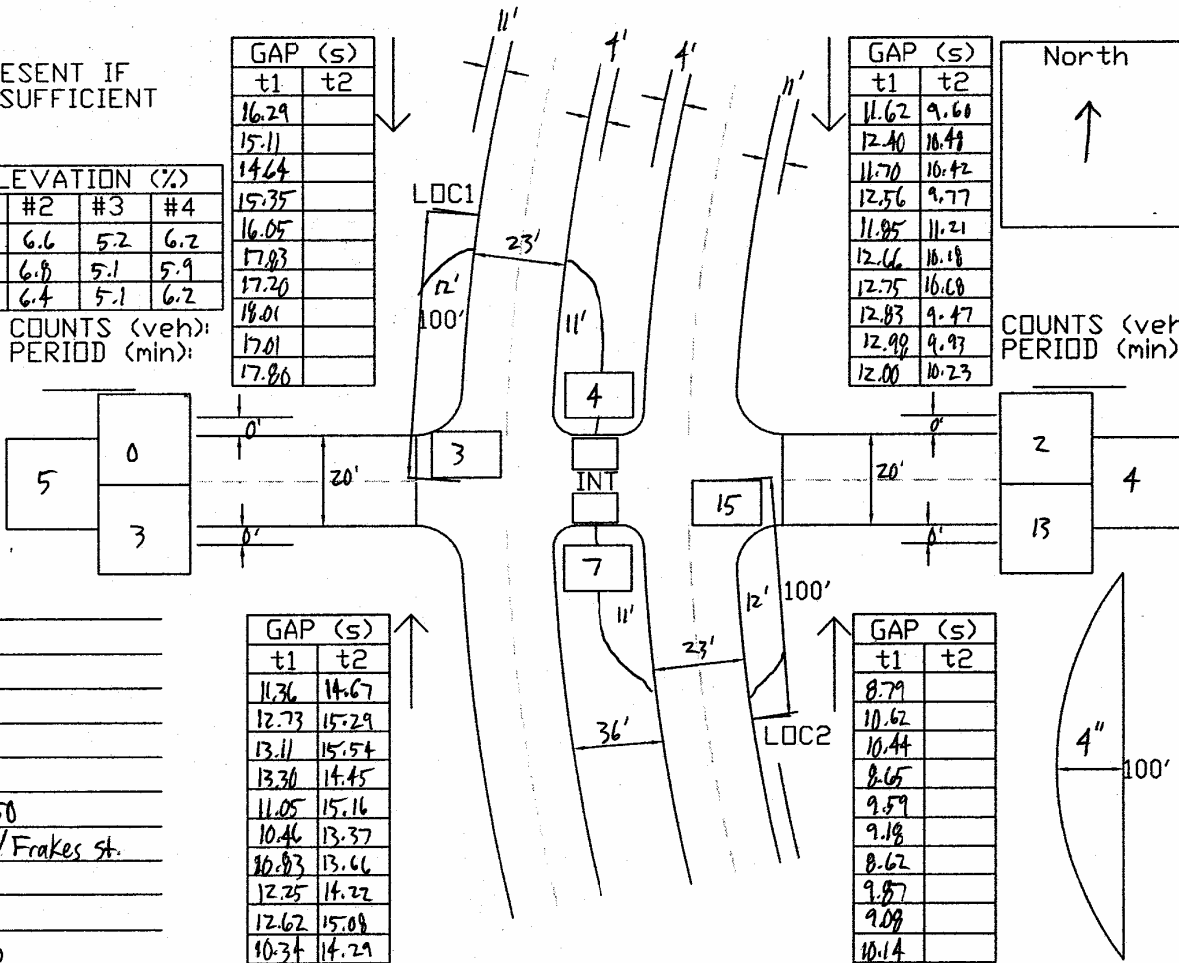


Figure A-45 Intersection of US-41 & Radio Ave. (Vanderburgh County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	0.5	1.0	0.9	1.1
LOC1	1.4	0.4	1.1	1.6
LOC2	0.1	0.6	1.0	1.1

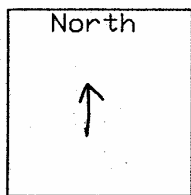
COUNTS (veh):
 PERIOD (min):

GAP (s)	
t1	t2
4.68	
4.82	
4.79	
4.90	
4.72	

GAP (s)	
t1	t2
66.01	
65.71	
59.92	
62.39	
64.22	
60.18	
61.47	
63.30	
64.19	
62.74	

GAP (s)	
t1	t2
18.16	15.43
19.82	17.63
18.09	15.76
19.48	16.29
19.76	17.48
18.91	16.66
19.36	17.05
16.52	15.29
16.23	15.44
18.14	16.20

COUNTS (veh):
 PERIOD (min):
 120



DATE: 07/13/03
 TIME: 1:30 PM
 WEATHER: Clear
 DISTRICT: Vincennes
 COUNTY: Vanderburgh
 OBSERVER: PS
 MAJOR ROAD: US-41
 MINOR ROAD: Radio Ave.
 SPEED LIMIT: 55
 CONTROL: TWFL
 VERTICAL CURVE: No

GAP (s)	
t1	t2

GAP (s)	
t1	t2
16.22	
17.54	
18.81	
19.21	
18.97	
19.65	
19.28	
19.41	
20.16	
19.98	

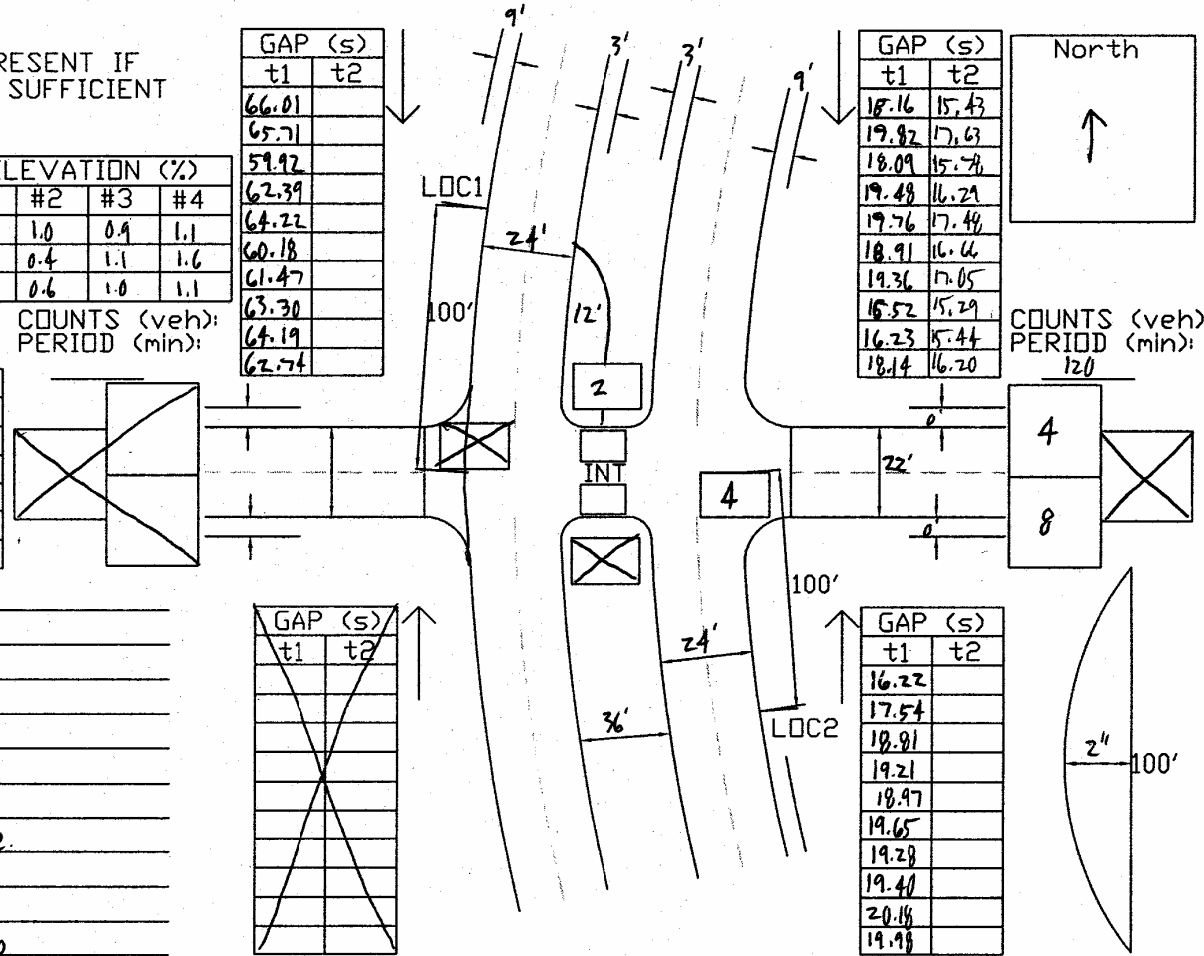


Figure A-46 Intersection of US-41 & Old State Rd. (Vanderburgh County)

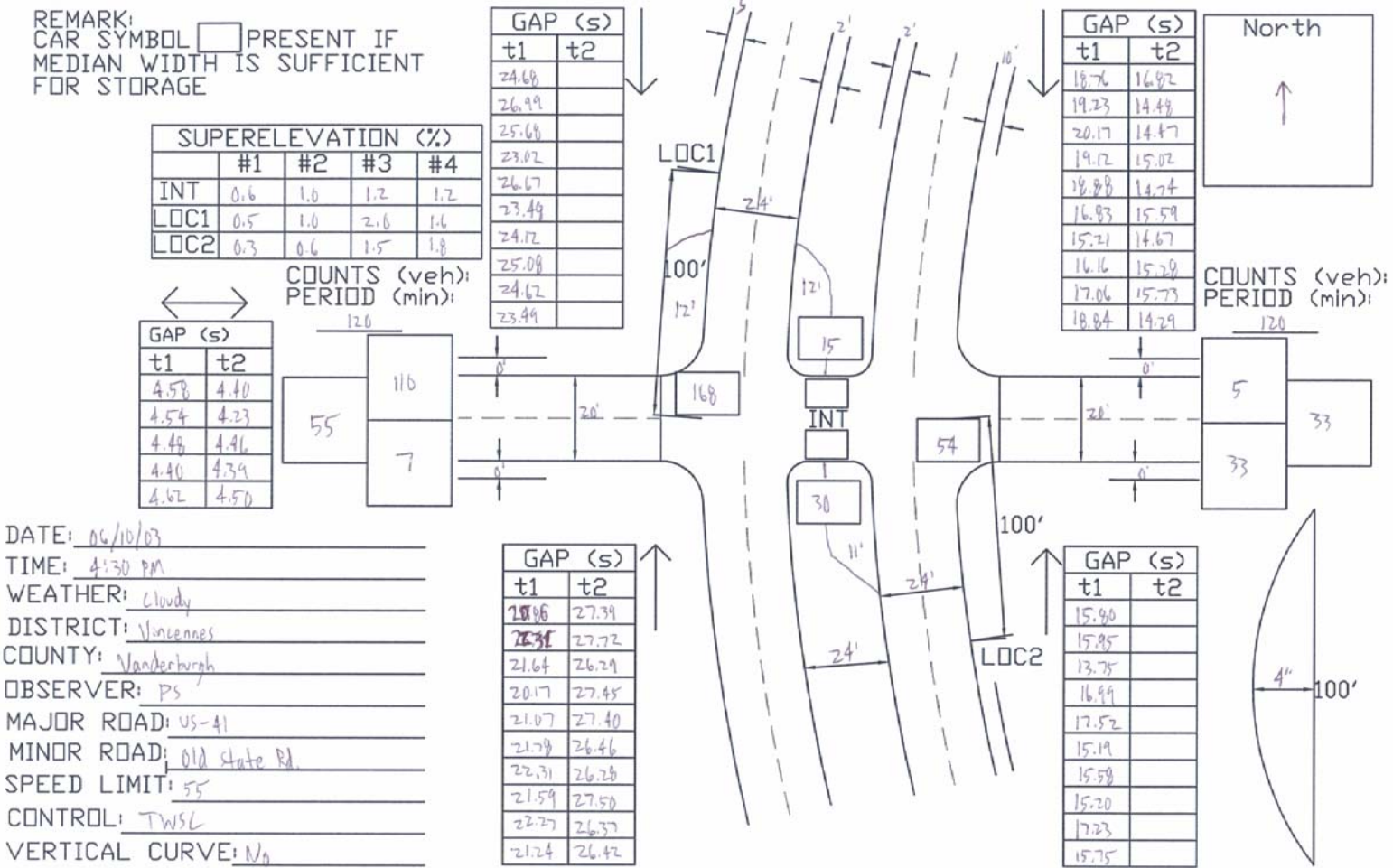


Figure A-47 Intersection of SR-62 & County Line Rd. (Posey County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	0.9	1.3	3.0	2.8
LOC1	0.9	1.3	3.1	2.8
LOC2	0.9	1.5	2.8	2.8

GAP (s)	
t1	t2
4.78	4.40
4.59	4.40
4.51	4.37
4.48	4.46
4.87	4.52

COUNTS (veh):
 PERIOD (min):
 120

7	5	20
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GAP (s)	
t1	t2
33.93	
36.95	
31.87	
32.07	
32.15	
34.39	
31.08	
32.44	
33.24	
32.61	

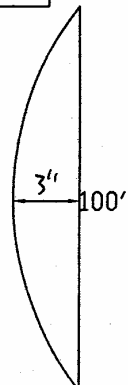
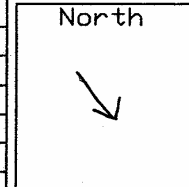
GAP (s)	
t1	t2
18.06	23.38
17.63	23.31
18.85	23.73
17.64	22.86
17.61	23.42
17.70	23.85
16.13	22.96
16.95	24.02
17.71	23.10
17.60	22.75

GAP (s)	
t1	t2
25.49	27.12
25.85	26.50
27.39	25.73
25.66	27.19
23.43	29.63
24.22	27.25
26.27	26.44
25.49	28.32
25.30	27.29
24.44	25.77

COUNTS (veh):
 PERIOD (min):
 120

22	9	36
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GAP (s)	
t1	t2
9.26	
9.40	
9.25	
9.16	
10.51	
9.97	
8.78	
10.98	
9.81	
9.26	



DATE: 06/12/03
 TIME: 12:00 PM
 WEATHER: Clear
 DISTRICT: Vincennes
 COUNTY: Vanderburgh/Posey
 OBSERVER: PS
 MAJOR ROAD: SR-62
 MINOR ROAD: Posey County Line Rd.
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

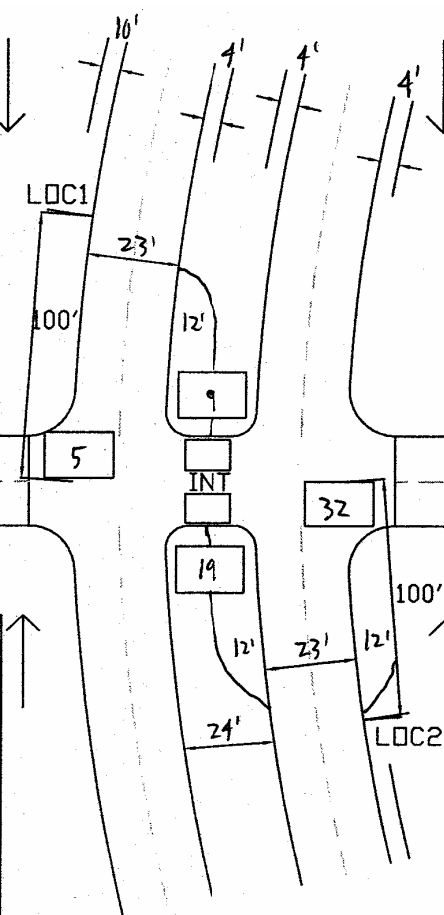


Figure A-48 Intersection of SR-62 & McDowell Rd. (Vanderburgh County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	6.9	6.9	3.0	3.0
LOC1	7.1	7.1	3.0	3.2
LOC2	7.0	7.0	3.0	3.0

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
4.16	4.20
4.58	4.57
4.70	4.41
4.23	4.34
4.46	4.50

3	113
	11

GAP (s)	
t1	t2
24.68	
25.26	
23.48	
24.32	
26.25	
27.65	
27.58	
25.68	
24.32	
24.88	

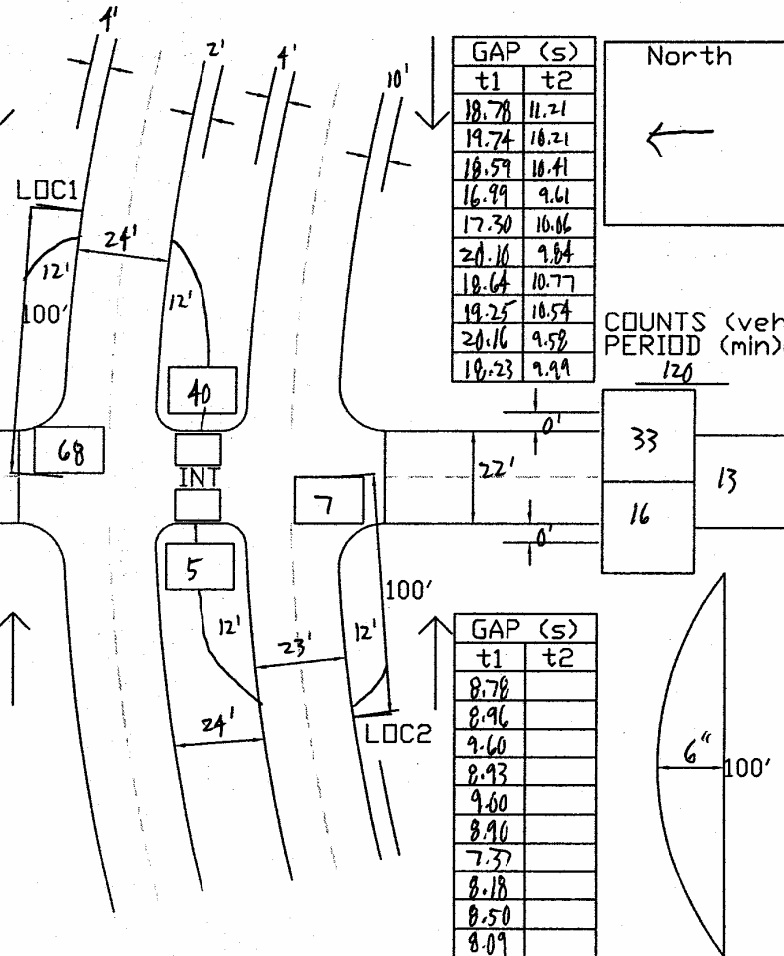
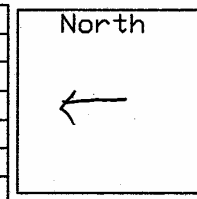
GAP (s)	
t1	t2
9.77	11.04
10.01	13.17
9.64	12.08
9.55	12.01
10.47	12.29
10.89	13.54
10.38	12.33
9.77	12.08
10.26	11.72
9.93	12.46

GAP (s)	
t1	t2
18.78	11.21
19.74	10.21
18.59	10.41
16.99	9.61
17.30	10.06
20.10	9.54
18.64	10.77
19.25	10.54
20.16	9.58
18.23	9.99

COUNTS (veh):
 PERIOD (min):
 120

7	33	13
	16	

GAP (s)	
t1	t2
8.78	
8.96	
9.60	
8.93	
9.60	
8.96	
7.37	
8.18	
8.50	
8.09	



DATE: 06/12/03
 TIME: 10:00 AM
 WEATHER: Cloudy
 DISTRICT: Vincennes
 COUNTY: Vanderburgh
 OBSERVER: PS
 MAJOR ROAD: SR-62
 MINOR ROAD: McDowell Rd.
 SPEED LIMIT: 55
 CONTROL: TWSC
 VERTICAL CURVE: No

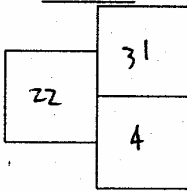
Figure A-49 Intersection of SR-66 & St. Joseph Rd. (Vanderburgh County)

REMARK:
 CAR SYMBOL PRESENT IF
 MEDIAN WIDTH IS SUFFICIENT
 FOR STORAGE

SUPERELEVATION (%)				
	#1	#2	#3	#4
INT	3.8	3.8	3.0	3.7
LOC1	3.3	3.3	3.9	3.7
LOC2	3.2	3.0	3.3	3.6

COUNTS (veh):
 PERIOD (min):
 120

GAP (s)	
t1	t2
3.98	4.14
4.31	3.89
4.00	4.09
4.19	4.28
3.80	4.15

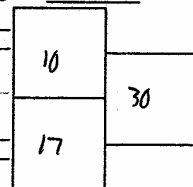


GAP (s)	
t1	t2
66.74	
66.04	
61.66	
66.90	
68.04	
62.67	
68.32	
65.24	
64.22	
66.12	

GAP (s)	
t1	t2
22.09	23.32
20.53	22.85
21.48	21.08
19.62	20.61
21.38	21.88
23.59	22.11
22.51	21.55
22.64	20.66
21.64	21.87
21.77	23.09

GAP (s)	
t1	t2
35.54	18.36
35.18	21.58
37.92	22.80
39.00	21.43
35.23	22.64
35.37	20.22
37.25	21.15
36.03	21.74
35.77	22.18
35.19	20.30

COUNTS (veh):
 PERIOD (min):
 120



GAP (s)	
t1	t2
22.48	
21.97	
21.03	
22.32	
20.84	
21.97	
21.72	
22.64	
22.19	
22.04	

