Research Report
KTC-03-12/SPR247-02-1F

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ROADWAY LIGHTING AND DRIVER SAFETY

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ROADWAY LIGHTING AND DRIVER SAFETY

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16. Abstract The objectives of this project were to: a) analyze the safety benefits associated with roadway lighting; b) determine the design of the lighting installation necessary to provide an adequate level of lighting; c) investigate how lighting affects the driver and the roadway's surrounding environment; d) review the economic correlation between effective lighting and cost savings for the State; e) provide input for updating the current section on street and highway lighting in the Traffic Guidance Manual; and f) analyze crash data to identify nighttime high crash locations. The procedure involved a literature search, a survey of states, crash data analysis, and collection of illumination data

The survey of states found that most states used information from either "An Informational Guide for Roadway Lighting" by AASHTO or "American Standard Practice for Roadway Lighting (ANSI/IESNA RP-8-00)" as a basis for their warrants and design of highway lighting. A procedure was developed to identify spots or sections that have a critical number or rate of nighttime crashes. An interactive nighttime critical rate analysis program was developed. Crashes at spots and intersections having a high number or rate of nighttime crashes were reviewed. A large number of the locations identified as having a high nighttime crash rate are rural locations where the nighttime crashes can be addressed with improved delineation (pavement markings and signage). The illumination data show that the AASHTO guidelines can be met with a limited number of properly located luminaires. For example, one luminaire placed across from the single approach at a "T-intersection" or two luminaries on diagonal quadrants of a "cross-intersection" (adjacent to the side street stop approach) were found to meet the guidelines if properly located.

17. Key Words

Roadway lighting	Nighttime crashes
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EXECUTIVE SUMMARY

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In addition, efforts by representatives of the states responding to the mail survey are acknowledged and appreciated.

GLOSSARY

Average Maintained Illuminance – The average level of horizontal illuminance incident on the roadway pavement when the output of the lamp and luminaire is diminished by the maintenance factors. Expressed in average footcandles or lux for the pavement area.

Average Maintained Luminance – The average level of luminance when the output of the lamp and luminaire are diminished by the maintenance factors. Expressed in average candelas per square foot.

Candela – The SI unit of luminous intensity. Formerly the term candle was used.

Footcandle – The illuminance of a surface one square foot in area on which there is uniformly distributed light flux of one lumen or the illuminance produced on a surface all points of which are at a distance of one foot from a directionally uniform point source of one candela. One footcandle equals 10.76 lux.

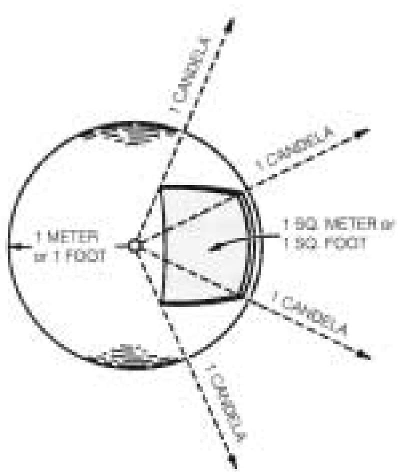
Illuminance – The density of the luminous flux incident on a surface. It is the quotient of the luminous flux by the area of the surface when the latter is uniformly illuminated.

Lumen – A unit of measure of the quantity of light. One lumen is the amount of light that falls on an area of one square foot every point of which is one foot from the source of one candela. A light source of one candela emits a total of 12.57 lumens.

Luminaire – A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

Luminance – The luminous intensity of any surface in a given direction per unit of projected area of the surface as viewed from that direction.

Lux – The SI unit of illuminance. It is defined as the amount of light on a surface of one square meter all points of which are one meter from a uniform source of one candela. One lux equals 0.0929 footcandle.



The figure at the left shows the relationship between candelas, lumens, lux, and footcandles: A uniform point source is shown at the center of a sphere of unit radius. The illuminance at any point on the sphere is one lux (one lumen per square meter) when the radius is one meter, or one footcandle (one lumen per square foot) when the radius is one foot.

1.0 INTRODUCTION

Visibility of the roadway decreases as light diminishes thereby making it more difficult for a driver to maneuver safely. Roadway lighting is a method to increase driver safety with research suggesting that 40 to 60 percent of nighttime road crashes could possibly be avoided by the addition of lighting (1). Therefore, a justification for roadway lighting is the cost savings from crash reductions. Although estimates vary, the savings from roadway crashes after a few years may be enough to pay for a lighting installation.

Many urban highways include some application of roadway lighting; however, most rural highways and roads with lower functional classifications do not have roadway lighting. Also, many intersections with high crash frequencies and high crash rates are not lighted. Increased use of roadway lighting has the potential to improve highway safety in many applications across the state.

However, the installation of roadway lighting may create other problems that must be addressed. Problems arise regarding the glare from the lights, the correct height and angle of the lights, the benefits of horizontally or vertically mounted lights, and light trespass or pollution. Using a method to identify locations that have a high number or rate of nighttime crashes and considering the potential problems associated with roadway lighting would provide an opportunity for cost savings for both the Kentucky Transportation Cabinet and the driving public.

2.0 OBJECTIVES

The objectives of this project were to: a) analyze the safety benefits associated with roadway lighting; b) determine the design of the lighting installation necessary to provide an adequate level of lighting; c) investigate how lighting affects the driver and the roadway's surrounding environment; d) review the economic correlation between effective lighting and cost savings for the State; e) analyze crash data to identify nighttime high crash locations; and f) provide input for updating the current section on street and highway lighting in the Kentucky Transportation Cabinet's Traffic Guidance Manual to reflect the findings of this study.

3.0 METHODOLOGY

3.1 Literature Search

A literature search was conducted to identify studies that have addressed the related roadway lighting issues to be considered in this study. The specific issues included warrants for the installation of roadway lighting, the design of roadway lighting, and the positive and negative results from roadway lighting.

Summaries were made of the relevant sections of reports identified as providing information that could be used to achieve the objectives of this study.

3.2 Survey of States

A survey was mailed to all the states to obtain information concerning their roadway lighting procedures. A copy of the survey form is presented in Appendix A. The questions dealt with warrants used to place lighting, guidelines for required illuminance to be provided by the lighting, design of the lighting installations, and before and after crash studies.

3.3 Crash Data Analysis

Crash data were obtained from Kentucky's Collision Report Analysis for Safer Highways (CRASH) database for the years 1999 through 2001. The data included all crashes occurring on state-maintained roadways. Each record is coded according to the amount of sunlight and the presence of roadway lighting. The following six codes are used on the police report to describe lighting conditions at the time of the crash.

1. Daylight
2. Dusk
3. Dawn
4. Darkness-roadway lighting on
5. Darkness-roadway lighting off
6. Darkness-no roadway lighting

Codes 1 through 3 (dawn, daylight, and dusk) were considered daytime and 4 through 6 (darkness; lighted/off, lighted/on, not lighted) were considered nighttime. Codes 5 and 6 were considered as "nighttime with no lighting." The database was separated into three groups; all crashes occurring during daylight hours, and all crashes during nighttime hours, and crashes during nighttime hours with no roadway lighting.

3.3.1 Crash Characteristics

Comparisons were made between the characteristics of crashes occurring during daylight with those occurring during nighttime conditions. Only records with the "no lighting" code were used in analysis for the nighttime database. This process included a comparison of all crashes as well as only fatal crashes.

3.3.2 High Crash Locations

Methodologies to identify high crash locations have been developed to identify sections of roadways with a high number of crashes. This methodology requires the use of critical numbers of crashes. These critical numbers serve as an initial "cut-off" point for consideration as a high-crash spot or section. Critical numbers were calculated using the following equation:

$$N_c = N_a + K\sqrt{N_a} + 0.5 \qquad \text{(Equation 1)}$$

in which

N_c = critical number of crashes
N_a = average number of crashes
K = constant related to level of significance
(a probability of 0.995 was used wherein K = 2.576)

Nighttime volumes were necessary to accurately calculate nighttime crash rates. The times of sunrise and sunset by month were tabularized since the hours of daylight changes throughout the year. These tables were used to determine which hours, during a specific month, could be considered "dark." Data from a previous report were used to define nighttime hours (2). In that study, the hours of sunrise and sunset were obtained from the Weather Bureau.

After accounting for the two different time zones within the state and daylight saving time, the hours of daylight and darkness were defined for each month. Dawn was defined as the hour before sunrise (rounded to the nearest hour); dusk was defined as the hour after sunset. For the data analysis, nighttime hours were defined as the hours between the end of dusk to the start of dawn. A table (obtained from traffic volume counts) listing the percent of average daily traffic (ADT) by hour was combined with the times of darkness. This was created for four different roadway types. The resulting table identified the percentage of the ADT during nighttime conditions for each of their highway types.

A method was developed to identify high crash locations within the crash database. A computer program was written in FORTRAN to automate this process. The program, called C2, identified the number of roadway sections or spots within a crash database that satisfied specific criteria. The criteria are defined by the spot or section length and the critical number of crashes that occurred during a specified time period within the spot or section length.

The C2 program was used with the "no lighting" portion of the nighttime crash database to identify two criteria: the number of 0.3-mile spots having three or more crashes and the number of intersections having two or more crashes. Only crashes occurring at intersections (as indicated by the directional analysis code on the police report) were included in the intersection analysis. Additionally, a spot length of 0.005 miles (26 feet) was used in the intersection analysis to limit the crashes chosen to those occurring within one intersection.

The next step in the methodology involved the calculation of a critical rate factor (CRF). The following formula was used to calculate a critical crash rate for each spot or section identified as meeting the criteria for critical number of crashes.

$$C_c = C_a + K\sqrt{\frac{C_a}{M}} + \frac{1}{2M} \quad \text{(Equation 2)}$$

in which

- C_c = critical crash rate
- C_a = average crash rate
- K = constant related to level of statistical significance selected (a probability of 0.995 was used wherein K = 2.576)
- M = exposure (for sections, M was in terms of 100 million vehicle miles (100 MVM); for spots, M was in terms of million vehicles (MV)

The crash rate for each spot or section identified as having a critical number of crashes was calculated. This rate was calculated using the number of nighttime crashes divided by the exposure, which was calculated based on an estimate of the nighttime volume. The crash rate was divided by the critical rate for that spot or section to determine the CRF. If the CRF was one or more, the spot or section could be investigated further. The number of locations which could be reasonably investigated would be considered when determining the CRF above which a more detailed analysis would be performed. The C2 program used this process to calculate a CRF for each spot or section identified as having a critical number of crashes.

The procedure was used to develop an interactive program that could be used to access nighttime crashes for a certain time period and identify high crash spots and sections.

3.3.3 Before and After Crash Analysis

A list of intersections where roadway lighting had been installed in the past few years was obtained from one highway district. This list was used to analyze the effect that roadway lighting had on the number of nighttime crashes. Nine intersections were used in the analysis with the number of crashes per year obtained for up to four years prior to the lighting installation and three years after installation. In several cases, only one year of data was available after installation.

3.3.4 Crash Site Investigation

A sample of crash sites identified by the high crash analysis was investigated to determine the characteristics of the crash sites, types of crashes, and potential recommendations to reduce the number of crashes. Lists of 0.3-mile spots and intersections with the highest CRFs were obtained. Locations with the highest CRFs were inspected.

3.4 Illumination Data Collection

In order to assist in determining the design of the lighting to be placed at a specific location, the illumination provided by various numbers of luminaires placed at different locations at an intersection was obtained. The illuminance was measured using a Minolta T-10 Illuminance Meter. Measurements were taken at several points within the intersection to determine the average illuminance within the boundary of the intersection as well as the uniformity of the illuminance within the intersection. Various methods of data collection, using different patterns of collection points, were used to determine the most efficient process. Data were obtained at various types of intersections having different numbers and arrangements of luminaires. Additionally, luminaire wattage, height, and relative position were collected.

4.0 RESULTS

4.1 Literature Search

Three publications were found to contain a substantial amount of information concerning roadway lighting. These publications were: "An Informational Guide for Roadway Lighting" (3) published by the American Association of State Highway and Transportation Officials (AASHTO), "American National Standard Practice for Roadway Lighting (ANSI/IESNA RP-8-00)" (4) published by the Illuminating Engineering Society of North America, and "Report 152 - Warrants for Highway Lighting"(5) published by the National Cooperative Highway Research Program (NCHRP). Following is a discussion of how these and other publications address the relevant issues.

4.1.1 Warrants for Roadway Lighting

Considering financial constraints, questions are often asked as to why we need to light the roadway. The need for lighting a particular roadway is determined when certain factors such as traffic volume, speed, road use at night, night crash rate, road geometrics, and general night visibility are considered and minimum conditions are met which justify the need. In some cases, the condition may not warrant full illumination and only partial illumination may be adequate.

The following is a summary of two publications that were found to contain warrants which have been widely used for roadway lighting.

An Informational Guide for Roadway Lighting (3), published by AASHTO, divides the warrants into freeways (including continuous freeway lighting, complete interchange lighting, and partial interchange lighting), streets and highways (other than freeways), tunnels and underpasses, and rest areas. In this report, only the first two categories will be discussed. These AASHTO warrants are listed in Appendix B. In general, the warrants consider such factors as average daily traffic volumes on the mainline, ramps, and crossroads; interchange spacing; adjacent roadway lighting; and crash rates. In addition, hazardous locations on rural highways, governmental agency desires, and severe weather locations are considered.

NCHRP Report 152 entitled Warrants for Highway Lighting (5), divides the warrants into four categories: non-controlled-access facilities, controlled-access facilities, intersections, and interchanges. Tables are listed that contain worksheets that rate different geometric, operational, and environmental factors plus crashes (Appendix C). The minimum warranting condition is the total effectiveness achieved by lighting a traffic facility with an average rating of 3 on the subjective scale of 1 to 5 for each classification factor. For example, the minimum warranting condition for continuous arterial lighting is 85 points. These 85 points represent a facility where all geometric, operational, environmental, and crash parameters have a rating of 3. To calculate the number of points for a facility, the rating number (X) for each classification factor multiplied by the difference between the unlighted weight (A) for each factor and the lighted weight (B) for each factor equals the minimum warranting number of points for that factor or X(A-B). All the points are then totaled and compared with the 85 point warranting condition. If a given continuous arterial traffic facility received a 3 rating for each geometric, operational, environmental, and crash parameter, the facility would just meet the minimum requirements for lighting. Any combination of ratings that will produce a total of 85 points or more would be warranted. The degree to which the total warranting points exceed the minimum serves as the basis for setting priorities.

The American National Standard Practice for Roadway Lighting (ANSI/IESNA RP-8-00) (4), published by the Illuminating Engineering Society of North America, does not contain warrants for roadway lighting. This publication is used once lighting warrants have been met. It contains information regarding the road surface classification, recommended values for the uniformity ratio, average luminance, and maintained illuminance, as well as design criteria and configurations.

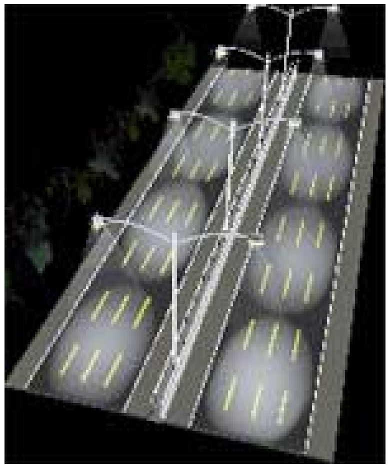
4.1.2 Design of Roadway Lighting

Once lighting warrants have been met, the selection of the appropriate light fixture design must be determined. A number of factors may be considered for the design of a lighting application. These factors include style of fixture, height, placement, lamp type, brightness, color, expected length of service, and cost efficiency.

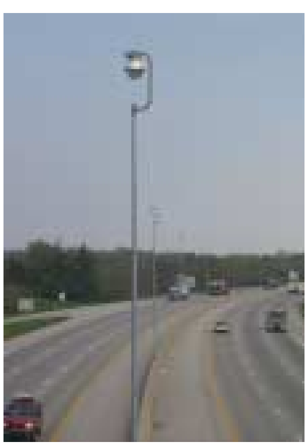
Style of Fixture

Selection of a fixture type depends to a large extent on where it is to be placed. This also affects the number and positioning of fixtures. Following is a discussion of the most common fixture types.

The horizontal luminaire, also known as the cobrahead, is mounted on a bracket extending horizontally from the light pole (shown on the next page). This is perhaps the most commonly used roadway lighting fixture, and offers the widest selection of wattages and lamp types. Most conventional cobrahead poles have one or two luminaries and have a maximum height of 30 to 50 feet. While it does not provide the expansive light spread thrown by high-mast fixtures, horizontal luminaries do light large areas. Depending on their configuration, they can also provide control of spill light. Horizontal luminaries cost less than other types of fixtures, so they are usually specified when cost is a key factor. One disadvantage of the horizontal luminaire fixture is the obvious hot spot of light directly under the pole. Another disadvantage is the maintenance of the fixture, which requires closing one or more lanes of traffic in both directions to service the system. Safety for the maintenance workers is also an added concern.



Vertically lamped median-mounted lighting systems can be used in place of horizontal luminaries where applicable (shown below). These fixtures can replace two or more cobrahead fixtures used in traditional designs. These systems usually have a lower installation cost and, because the lighting mandates fewer poles and fixtures, a much lower energy and maintenance cost. Maintenance costs are further reduced because it is only necessary to close one lane of traffic, with all maintenance repairs made from that lane.



The term “high-mast” is used to describe any lighting structure that rises at least 60 feet above the road level. Depending on the design, high-mast applications can extend up to 150 feet or higher and are not normally used in urban areas. A single pole can be used to support a cluster of three to a dozen luminaries placed in a large ring on the outside of the pole (shown below).   For basic maintenance, the ring of luminaires is lowered as a group to ground level.

When high-mast lighting can be justified, it offers several advantages to other types of lighting. One major advantage is the large, even field of distributed light. High-mast lighting gives drivers a wide view of the roadway, which makes it easier to identify converging or diverging traffic patterns. High-mast also offers economic benefits in basic maintenance. There is no urgency to replace a bulb when one burns out since there are from three to twelve luminaires on a single pole. Manpower use and hazards to workers are reduced for high-mast lighting systems since traffic does not have to be interrupted for maintenance.   Fewer poles located farther from the edge of the pavement (minimum of 50 feet) reduce the possibility of car-pole crashes. Also, there is usually no need to relocate high-mast poles if the roadway is reconstructed or widened. Disadvantages include light trespass and light pollution issues. These issues are discussed in the next section. High-mast lighting also loses some light intensity that conventional cobraheads offer and higher energy costs are required for high-mast systems.

Height

Mounting height of the fixture is generally determined by the lamp output and the desired average illumination on the roadway. In general, higher output luminaires are mounted higher. Mounting heights of 60 feet or higher are called high-mast lighting.

In addition to the height of the pole, the material of the pole also needs to be selected. Wood, metal, or concrete poles are usually used for lighting fixtures. Many types and styles of poles are available. From a safety standpoint, aluminum and stainless steel on breakaway hardware are the materials of choice. The popularity of steel stems from reasonable prices, tradition, and color options. Stainless steel poles are attractive, strong, and relatively maintenance-free. The tapered aluminum pole is also extensively used. Aluminum is lightweight, which makes installation easy and economical. Tests and experience have proven that aluminum poles resist corrosion. Concrete poles are moderately expensive but require little long-term maintenance. They usually do not exceed 50 feet in height. Innovations in pole technology have seen the development of the fiberglass pole. Available in lengths up to 45 feet, the poles are lightweight and require only a small crew for installation. They are also corrosion and stain resistant.

Placement

Luminaire placement is an integral part of the design of an effective lighting system. Luminaires are mounted at specific points along the roadway, depending on the character of the roadway to be lighted. For roadways not having medians, the luminaire is normally installed on the side of the roadway. For streets having medians, a median mount lighting system provides very effective lighting at less cost because of the saving in luminaire supports and energy.

Criteria have been developed to locate the poles at a safe distance from the road in relation to design speed. Special breakaway bases are employed where poles have to be located close to the roadway.   An example of a breakaway base is shown below.

Lamp Type

The lighting fixture or luminaire consists of three parts: the lamp, the reflector or the metal surface behind the lamp, and the refractor which is the glass or plastic lens that encloses the lamp and is made up of light-directing prisms.

Roadway lighting generally uses lamps from the gas discharge family. The light from this type of lamp is produced when the electric current passes through a container of gas, causing the energized gas to give off characteristic bands of color. These lamps include high-pressure sodium, low-pressure sodium, metal halide, and mercury vapor. Service life, lumen efficiency, color rendering, optical control, and cost of operation and maintenance are considerations when choosing which type to use.

High-pressure sodium lamps are the most commonly used light source for highway lighting. This is because they have a long operating life (an average of 24,000 hours), high lamp efficacy, and are relatively small in size. The small size allows controlled use of the light output when used with efficient reflectors, refractors, and lenses. Their disadvantage is a pinkish/orange color rendition and a long restrike time in the event of momentary power interruption.

Low-pressure sodium lamps also have a high lamp efficacy; however, they do not have as long an operating life as high-pressure sodium or mercury vapor lamps. They have a relatively short restrike in the event of momentary power interruption. The cost of installation and maintenance can be a major consideration in product selection. These lamps have a very large arc tube, which makes it difficult to efficiently control the light output from the lamp. Low-pressure sodium lighting produces a monochromatic yellow tint.

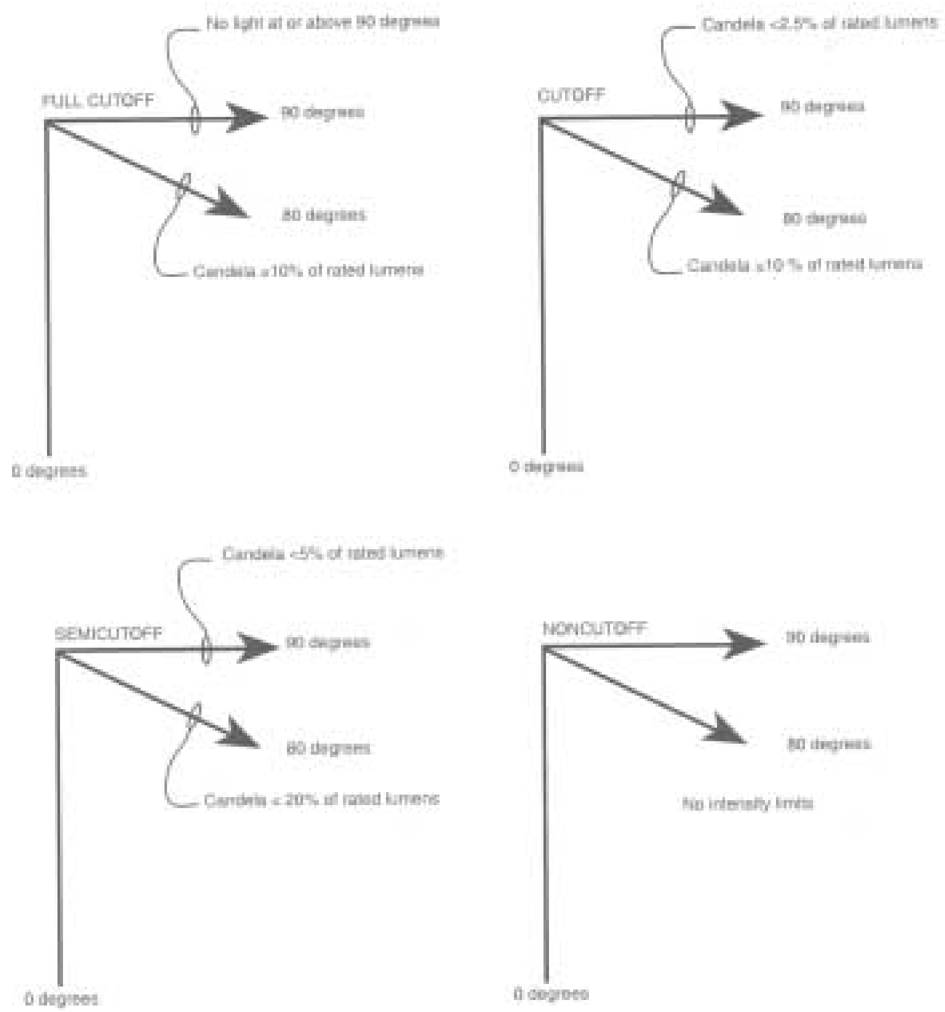
Metal halide lamps have found only limited use because of their relatively short lamp life. However, these lamps have a very good color rendition, have a moderate to high lamp efficacy, good light control because of the small size, and produce a light that is bluish white in color.

Mercury vapor lamps offer an exceptionally long operating life, but have a lumen efficiency only about half that of high-pressure sodium lamps. Mercury vapor lamps produce a light that is bluish white in color.

Below is a comparison of the various lamps that are used in roadway lighting (6).

Type of Lamp	Range of Efficacy (lumens/watt)	Rated Average Life (hrs.)	Color Rendition	Optical Control	Initial Lamp Cost	Operational Cost
Mercury Vapor	25 – 60	24,000+	Fair	Good	Moderate	Moderate
Metal Halide	45 – 100	7,500-15,000	Good	Good	High	Low
High-Pressure Sodium	65 – 125	20,000-24,000	Fair	Fair	High	Low
Low-Pressure Sodium	100 – 180	18,000	Poor	Poor	High	Low

The reflector and refractor are used to control the distribution of light on the roadway. The categories of control include full-cutoff, cutoff, semi-cutoff, and non-cutoff. These control measures minimize light output from the fixture at angles of 80 to 90 degrees and above (see figure below). To address skyglow issues, roadway lighting luminaires should at least be semi-cutoff; however, cutoff and full-cutoff luminaires should be strongly considered.



4.1.3 Consequences of Roadway Lighting

The driving public demands lighted roadways both for safety and security reasons. However, property owners generally do not want any stray light on their property. Two terms are generally used to describe property owner concerns: light trespass and light pollution. While these terms are often used interchangeably, they actually describe two distinctly different phenomenon, often caused by the same streetlight.

Light trespass is the shining of light produced by a luminaire beyond the boundaries of the property on which it is located. This light can be measured and quantified. Light pollution or "skyglow" is the actual brightness of the fixture that can be seen miles away and causes domes of lights over cities. Some studies suggest that roadway lighting causes as much as 50 percent of the skyglow in our major urban areas.

Many cities have adopted ordinances against light trespass and light pollution in an attempt to reduce skyglow. However, there are other measures to combat light pollution and light trespass when designing roadway lighting:

- Use of cutoff luminaires so that luminaires are not visible in roadway lighting fixtures, except from directly beneath them
- Design lighting installations that provide the minimum amount of light needed for safety

Even though lighting provides increased safety and security, it should be applied in a manner sensitive to these environmental issues in order to minimize negative consequences.

4.1.4 Cost of Roadway Lighting

One justification for highway lighting is in terms of a cost savings for property damage due to crash reductions. Although estimates vary, the savings can be enough to pay for a lighting installation in a few years.

Conventional roadway lighting usually refers to cobrahead lighting systems. General estimates place conventional lighting at $5,000 - $6,000 per pole. High-mast systems cost more per unit than conventional cobraheads. High-mast units cost a minimum of $30,000 - $40,000. However, with high-mast units, there are anywhere from 6 to 12 separate luminaries and maybe one-sixth as many lighting assemblies. With design and maintenance costs factored in, high-mast units generally have a 20 percent long-range savings over conventional methods (7).

Where applicable, vertically lamped median-mounted lighting systems can reduce costs over traditional cobrahead lighting systems at a ratio of one median mount fixture for every two cobrahead fixtures. Besides a reduction in installation costs and energy consumption, a major benefit is 50 percent less maintenance. The median mount fixtures require that only one lane be closed, with all repairs made from that lane. The time required is cut in half, making the cost for closing the road 50 percent less. While the initial investment for a median mount lighting system may average 25 percent more, the cost can be justified by the savings incurred in operating and maintenance costs each year (8).

4.2 Survey of States

Responses to the survey were obtained from 33 states with information obtained from other sources for three additional states. A summary of the responses can be found in Appendix D. Following is a general discussion of the answers to the four questions on the survey.

1. Do you have specific warrants for the placement of lighting (other than that given by AASHTO in “An Information Guide for Roadway Lighting”)?

Fourteen states indicated they had specific warrants not given in the AASHTO publication. A summary of these warrants is presented in Appendix E. The most common warrant dealt with the number of nighttime crashes such as a specific number of crashes within a given time period. Other types of factors included in the warrants were traffic volume, roadway geometry, adjacent development, and type of roadway.

2. Do you have guidelines for the “average maintained illuminance” to be provided by the lighting other than that given in the AASHTO publication?

Ten states noted they had other illuminance guidelines. The other source listed most often was ANSI/IESNA RP-8. A comparison of several illumination guidelines is shown below. A complete summary of the illumination guidelines for the States, ANSI/IESNA RP-8, NCHRP 152, and AASHTO are given in Appendix F.

Roadway Class	AASHTO[1]	ANSI[2]	NCHRP	CA[3]		IN	MO	NJ	WA[4]
				Rural	Urban				
Freeway	n/a	n/a	0.6	3.2	0.6	0.74	0.6	.59 - .8	.6 - .9
Expressway	.6 - .9	n/a	1	6.5	0.6	1.16	0.6	.59 - .8	.6 - .9
Major	.6 - 1.1	1.8 - 3.4	1	3.2	0.6	n/a	0.6	.59 - .8	.6 - .9
Collector	.4 - .7	1.2 - 2.4	0.6	3.2	0.6	n/a	0.4	n/a	.6 - .9
Local				3.2	0.6	n/a	0.4	n/a	.6 - .9
Intersections	n/a	n/a	n/a	n/a	n/a	0.84	0.6	.59 - .8	n/a

[1]Illinois, Minnesota, and Oklahoma reported using the AASHTO guidelines for illuminance

[2]Alabama, Maryland, and New York reported using the ANSI guidelines for illuminance

[3]Guidelines are given for the centerline of entering streets

[4]Values depend on pedestrian classification

3. Do you have guidelines for the design of lighting installations (number and placement of luminaires) to achieve the desired illuminance?

Ten states gave guidelines they used for the design of lighting installations. Examples for lighting configurations given in the ANSI/IESNA RP-8 publication and various state guidelines are shown in Appendix G.

4. Has your state conducted any before and after studies to determine the benefits and costs associated with lighting?

Only three states noted they had conducted any before and after studies in order to estimate the change in the number of crashes after the installation of roadway lighting. No specific data were provided.

4.3 Crash Data Analysis

Following is a summary of the characteristics of nighttime crashes, the identification of high crash locations, a before and after analysis of crashes, and a description of the analysis of crashes occurring at a sample of high crash locations.

4.3.1 Crash Characteristics

The characteristics of crashes during daylight were compared with those occurring during darkness with no roadway lighting. This comparison was made for all crashes and fatal crashes using 1999 through 2001 crash data. Summaries of the data are given in Table 1 and 2 for all crashes and fatal crashes, respectively. Following are summaries of differences found in these comparisons.

Comparison of Characteristics of Crashes Occurring During Daylight with Crashes Occurring During Darkness with No Roadway Lighting

Variable	Comparison
Severity	Crashes occurring during darkness were more severe than during daylight.
Day of Week	A higher percentage of crashes during darkness occurred on weekends.
Number of Vehicles	A much higher percentage of crashes during darkness involved only one vehicle.
Surface Condition	Snow and ice conditions were present in a higher percentage of nighttime crashes.
Road Character	The percentage occurring on a curve was higher during darkness.
Month	The percentage varied as the number of hours of daylight changed with substantially more during daylight between June and August and much more during darkness between December and February (when there were more hours of darkness).
Directional Analysis	The percentage at an intersection was much higher during daylight conditions. Rear end collisions were more common during daylight. The types of crashes occurring more often during darkness were fixed object, run off roadway, animal, and shoulder/parked vehicle.

Type Crash/1st Event	Crashes during daylight had a much higher percentage involving another vehicle while those during darkness more often involved a fixed object or animal (especially a deer).
Counties	There was a lower percentage during darkness in the highest population counties of Jefferson, Fayette, and Kenton.
Contributing Factors	Factors listed substantially more often during darkness were animal action, alcohol, drugs, speed, and fell asleep. Factors listed substantially more often during daylight were failure to yield and inattention.

Comparison of Characteristics of Fatal Crashes Occurring During Daylight with Crashes Occurring During Darkness with No Roadway Lighting

Variable	Comparison
Day of Week	The percentage of crashes during darkness was higher on weekends.
Number of Vehicles	There was a higher percentage of single vehicle crashes during darkness.
Surface Condition	There was a slightly higher percentage on a dry surface during darkness.
Road Character	There were no major differences.
Month	The largest differences were a higher percentage during darkness between December and February with a lower percentage between June and August.
Directional Analysis	A higher percentage occurred during daylight at an intersection and involved a head on, sideswipe, or rear end collision. The percentage during darkness was higher for run off roadway, fixed object, wrong direction, and pedestrian crashes.
Type Crash/1st Event	A higher percentage of crashes during darkness involved a fixed object or pedestrian with a higher percentage during daylight involving another vehicle.
Contributing Factors	There was a much higher percentage involving alcohol during darkness. The largest difference during daylight was a higher percentage with failure to yield.

4.3.2 High Crash Locations

The objective was to identify locations having a high number and rate of nighttime crashes with a method developed that could be implemented in future years. The procedure first involved calculating the critical number of nighttime crashes for a specific time period for a specific length of roadway. Formula 1 (previously sited in Section 3.3.2) was used to calculate critical numbers of nighttime crashes for a three-year period (1999 through 2001). Data for this three-year period was analyzed as a trial procedure to consider for future years. After data for 2002 became available, the identification program was used to identify high crash locations for the period of 2000 through 2002. The results for this three-year period are provided (for further analysis) in Appendix H. The average number of crashes used in the formula was obtained using the number of crashes on each type of highway along with the number of miles on that type of highway. The following table gives the critical number of nighttime crashes in a three-year period (1999-2001) for each highway type.

	TYPE	**SPOT/SECTION LENGTH (mile)**		
		0.1	**0.3**	**1**
Rural	*All*	2	3	6
	2-Lane	2	3	5
	4-Lane	3	5	10
	Interstate	4	7	14
	Parkway	3	6	13
Urban	*All*	5	9	19
	2-Lane	3	6	12
	4-Lane Undivided	6	12	29
	4-Lane Divided	7	13	33
	Interstate	7	15	32

Crashes coded as occurring during darkness (with no roadway lighting) were identified for the three-year period of 1999 through 2001. A file containing these nighttime crashes was developed and sorted so that the crashes were ordered by county, route, and milepoint. The computer program previously described (C2) was used to identify spots or sections with a critical number of crashes. The program also calculated the crash rates for locations having a critical number of nighttime crashes. A critical rate factor (CRF) was then calculated for each location.

The percent of the average daily traffic (ADT) during nighttime hours was determined for various types of roadways. This percentage was used to estimate the nighttime volumes necessary to calculate the nighttime crash rate. The first information needed to determine nighttime traffic was the percent of total ADT traveled by hour for each roadway type (Appendix I). Using the times of sunrise and sunset by month (Figure 1), the percent of the ADT occurring during the hours of darkness was calculated by month and hour. The percentage of hours of darkness, as shown in Figure 1, is 41 percent. This analysis resulted in the following percentages of nighttime ADT by roadway type.

Highway Type	Percent
Rural Interstate/Parkway	20.1
Other Rural Roadways	16.1
Urban Interstate/Parkway	18.5
Other Urban Roadways	17.0

As a comparison, data show that about 30 percent of crashes in rural areas occur during darkness and about 22 percent of crashes in urban areas occur during darkness. The higher percentage of crashes during darkness compared with the percentage of volume during this time period shows the higher crash rate at night.

An example of the output from the C2 program is given in Figure 2 (using 1999 through 2001 crash data. This output is for 0.3-mile spots and is ordered by CRF. The data were for crashes occurring during darkness with no roadway lighting. The following information is given on the printout.

Field Name	Description
HD	Highway district number
CO	County number
RT	Route number
# CRASHES	Number of crashes occurring during darkness
BMP	Beginning milepoint
EMP	Ending milepoint
NK	Number of fatalities
NI	Number of injuries
NIGHTADT	Nighttime average daily traffic
RU	Rural/urban classification
NL	Number of lanes
MT	Type of median
FC	Functional classification
Cact	Actual crash rate
Crate	Critical crash rate
CRF	Critical rate factor

A summary of the 0.3-mile spots with a CRF of 1.0 or more (1999-2001) is given in Figure 3. This summary shows there were 2,851 spots having three or more nighttime crashes and no roadway lighting for the three years of 1999 through 2001. Of those, 782 had a CRF of 1.0 or more. The number of spots with a CRF of one or more was also summarized by county and highway district. The highest number of spots in one county was 30 in McCracken and Pike Counties.

A complete listing of the printout giving all 0.3-mile spots with a CRF of 2.0 or more (using 2000 through 2002 data for crashes during darkness with no highway lighting) is presented in Appendix H. A Critical Rate Factor of two was used because there were 1,276 spots with a CRF of one or more. A complete list can be produced upon request. A summary of all 0.3-mile spots with a critical number of three nighttime crashes for 2000 to 2002 crash data is shown in Appendix J. It should be noted that using a CRF of 1 results in an unreasonably high number of locations to feasibly investigate. The locations with the highest CRFs should be investigated to determine if lighting or additional delineation is justified. The cutoff for the CRF would be based on identifying a reasonable number of locations to investigate.

An analysis was done to identify intersections (using the directional analysis code and a length of 0.005 mile) with two or more crashes in the three-year period of 1999 through 2001 and a CRF of 1.0. A summary of this data is given in Figure 4. The summary shows there were 232 intersections meeting the criteria. A summary by county showed the largest number of intersections was in Jefferson County followed by McCracken County. A list of the intersections with three or more crashes (giving the crash rate) is given in Appendix K.

The procedure as previously described was used to develop an interactive program that could be used to access nighttime crashes for a specific time period and identify high crash spots and sections. The user inputs, on the nighttime crash buildup form, include the critical number and section length to consider. The program uses the nighttime crash file and the nighttime ADTs to obtain the number of spots or sections having a critical number of crashes. Then the user can choose to either display the data as a Excel spreadsheet or view a summary of the results in a Word document by clicking the display details or display summary buttons on the nighttime crash buildup form. For each location, the data base display shows the highway district number, county number, route number, number of crashes occurring during darkness, beginning milepoint, ending milepoint, number of fatalities, number of injuries, nighttime average daily traffic, rural/urban classification, number of lanes, type of median, functional classification, actual crash rate, critical crash rate, critical rate factor The word document summary shows the length and critical number considered, the number of spots/sections with the specified number of crashes, and the number of spots/sections with a CRF of one or more (total, by county, and by district). A more detailed description of the use of the interactive program is given in Appendix L.

4.3.3 Before and After Crash Analysis

Accident reduction factors (ARFs) have been developed at the University of Kentucky with the most recent publication of these published in 1996 (1). Contained in that report was an estimate that the addition of roadway lighting could reduce the number of nighttime crashes by about 50 percent.

A very limited amount of before and after crash data was obtained after the addition of lighting at intersections. Following is the number of nighttime crashes at several intersections in District 12 before and after the addition of lighting.

	Location	Installation Date	Crash Data*							
			1994	1995	1996	1997	1998	1999	2000	2001
Letcher	US 23 @ US 119	October 2000				0	3	0	**	1
	US 23 @ KY 805	October 2000				2	2	0	**	1
Floyd	US 23 @ KY 1426	October 2000				0	0	1	**	1
	KY 80 @ KY 680	March 1998		0	0	0	**	0	0	1
Lawrence	KY 3 @ KY 2565	June 1999				1	1	**	0	1
	US 23 @ KY 645	May 2000				2	0	1	**	0
Pike	US 23 @ US 119	June 1999				3	7	**	1	3
	US 119 @ KY 194	June 2000				1	0	0	**	0
Knott	KY 80 @ KY 160	March 1998	2	0	0	2	**	0	0	0

*Number of crashes per year
*Year of installation.

The data show there were not a large number of nighttime crashes at these intersections either before or after the lighting installations. It is interesting to note that the average number of nighttime crashes per year, using data from all the intersections, was reduced from 1.1 to 0.6 crashes after the lighting installation. This is a reduction of about 45 percent, which is very close to the Accident Reduction Factors (ARFs) given in the 1996 report (1).

4.3.4 Inspection of High Crash Locations

An analysis was conducted for 0.3-mile spots having the highest CRFs. These spots are given in Appendix H using 2000 through 2002 crash data. Following is a description of nighttime crashes at the 10 spots with the highest CRFs (using 1999 through 2001 data).

COUNTY	ROUTE	MILEPOINT	NUMBER	DESCRIPTION OF CRASHES
Madison	KY 1986	0.33-0.37	10	9 of the 10 crashes were fixed object; involved curve and railroad overpass
Laurel	KY 830	3.9-4.2	5	No pattern
Meade	KY 228	15.73-16	6	3 single vehicle run off road at curve; 2 involved pedestrian with 1 fatal
Harrison	KY 356	8.12-8.328	4	Fixed object crashes at curve
Montgomery	KY 713	13.73-13.981	6	3 involved driver on KY 213 not stopping at intersection with KY 713
Shelby	KY 53	11.42-11.64	9	5 fixed object and 4 opposite direction at curve and grade
Calloway	KY 280	3.8-4.1	5	All involved running off roadway in curve
Greenup	KY 503	5.38-5.581	6	No pattern
Warren	KY 263	0.57-0.77	6	3 involved a deer and others where driver ran off roadway in curve
Nelson	KY 46	4.951-5.25	4	2 involved a deer

Many of these locations were in rural sections where the roadway cross-section contributed to the loss of control. Additional delineation at curves or delineation of various fixed objects would address the types of crashes found at many of these locations.

The spots that had 10 or more nighttime crashes were also investigated. Following is a summary of the nine spots with 10 or more nighttime crashes (1999 through 2001 data) during darkness and no roadway lighting.

COUNTY	ROUTE	MILEPOINT	NUMBER	CRF	DESCRIPTION
Madison	KY 1986	0.33-0.37	10	4.5	9 of the 10 crashes were fixed object; involved curve and railroad overpass
McCracken	KY 1954	2.89-3.122	12	2.4	Single vehicle at curve at intersection of Husband Road and Clarkline Road
McCracken	US 68	0.99-1.01	10	1.8	Related to I-24 interchange
Scott	I-75	138-138.15	12	1.5	Most occurred during construction activity
Kenton	KY 1303	3.225-3.51	12	1.5	At Narrows Road intersection and curve close to intersection
Campbell	US 27	4.75-5	11	1.5	At intersections; rear end
Grant	I-75	148-148.25	10	1.4	No pattern
Jessamine	US 68	7.78-8	10	1.3	Single vehicle at curve and grade
Jefferson	KY 61	3.384-4.12	14	1.1	Most at intersections or driveways

These occurred at a wide range of locations. It should be noted that lighting was recently installed at the I-24 and US 68 interchange in McCracken County which had 10 nighttime crashes.

An analysis was conducted to identify the intersections with four or more nighttime crashes in the three-year period (1999 through 2001) that had no roadway lighting. The intersection with the highest number of crashes was at the I-24 interchange with US 68 in McCracken County which was also identified as a 0.3-mile spot with a high CRF. The intersection of KY 1954 (Husband Road) and Clarkline Road in McCracken County also was identified in the 0.3-mile spot analysis. Five of the 18 intersections were in McCracken County. Following is a list of these intersections.

COUNTY	ROUTE	INTERSECTING ROUTE	MILEPOINT	NUMBER
McCracken	US 68	I-24	1	6
Franklin	US 127	Burlington Lane	3.9	5
McCracken	KY 1954	Clarkline Road	2.92	5
Madison	US 421	KY 1016	7.98	5
Madison	KY 876	St. George Street	7.69	5
Boone	KY 18	KY 237	11.81	4
Campbell	US 27	Washington Street	10.38	4
Daviess	US 60	KY 2830	18.1	4
Daviess	US 231	KY 298	8.9	4
Fayette	US 27	Loudon	7.61	4
Jessamine	US 68	KY 169	7.31	4
Knox	US 25E	KY 3041	24.22	4
Lincoln	US 27	KY 1781	5.65	4
McCracken	US 45	KY 1241	0.26	4
McCracken	US 45	KY 1288	2.59	4
McCracken	KY 1954	I-24	3.62	4
Pulaski	US 27	KY 1642	12.3	4
Shelby	KY 55	Benson Park	8.03	4

4.3.5 Development of Interface to High Crash Identification Program

The program used to identify high crash locations was previously developed for in-house use. The program called C2 was programmed in FORTRAN. It involved the editing of text files for input and converted those text files into spreadsheets for analysis and sorting capabilities. The decision was made to develop a more "user friendly" interface to simplify the process of identifying high crash locations.

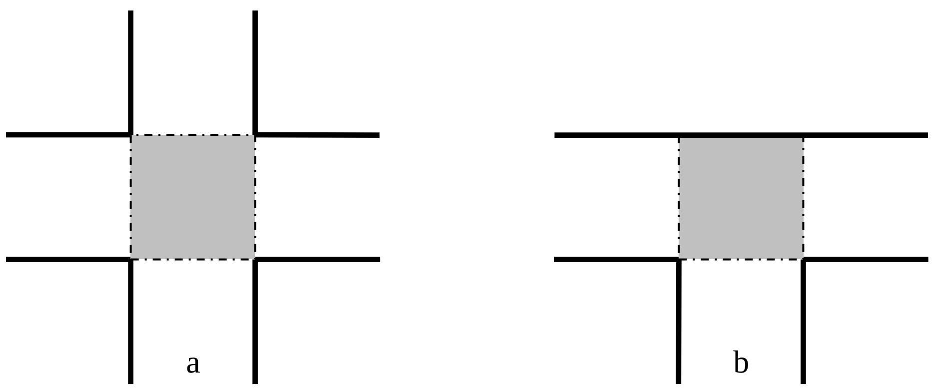
The program was converted into Visual Basic and linked to an Access database comprised of all nighttime crashes. A visual "front end" was included to allow the user to select from several conditions to identify the high crash locations. The program also allows the user to display the results in tabular form or as a summary.

The program begins by allowing the user to choose a spot or section analysis. In the spot analysis, options can be selected for either 0.1- or 0.3-mile spots. The user can also choose to analyze one of the 12 highway districts or all highway districts (default option). The user must enter a critical number and has the option to choose severity. The severity options include: all crashes, fatal crashes only, or fatal and injury crashes only. Once these options are chosen, the user clicks a submit button and the data can be viewed in one of two ways. The user can choose "Display Details" to view a Microsoft Excel spreadsheet of all the identified spots. The data fields are similar to that of the output from the original C2 program as seen in Figure 2. The data can also be displayed in summary by choosing "Display Summary." This option opens a Word document summarizing the results. The format is identical to the output provided by the original C2 program and can be seen in Figure 3. A step-by-step process for using this program, including screenshots, is shown in Appendix L.

The program is currently available using 2000 through 2002 crash data. It can be used to analyze high nighttime crash locations on a statewide or district basis using spots or sections. It is contained in a CD format with the source code included.

4.4 Illumination Data

Illumination data were collected at a variety of intersections with various arrangements of luminaires. The first step in this portion of the project was to determine the method to use to obtain the data. Several data collection patterns were used to determine the most efficient, yet accurate data collection procedure. A select number of randomly chosen sites were used to develop this procedure. All data were collected at intersections within the area shared by both intersecting roadways (see figures below).



Data collection boundary for cross (a) and tee (b) intersections.

4.4.1 Procedure Development

Initially, the data were collected in accordance with AASHTO's procedure for measuring luminance on a continuously lighted roadway (3). The data were collected at intersections in segments parallel to the major roadway. Two line segments were collected per lane; one line segment halfway between the centerline of the lane and the edgeline of the road, the other line was halfway between the centerline of the lane and the start of the adjacent lane. For example, four segments of data were collected for a two-lane roadway (one lane each direction). Data was collected along each segment for one luminaire cycle (the distance between two luminare poles). The number of points collected was defined by the luminaire cycle divided by 10, not to exceed 5 meters (16.4 feet) between points. As previously noted, this methodology was developed for continuously lighted roadways, not for intersections.

Data were collected at several sites using this methodology. Several alternative data collection patterns were considered. The average luminance was computed for all the data points at each site. This average was compared to a modified average obtained by removing some of the data points. The data points chosen for removal were based on several different collection patterns. The patterns used were:

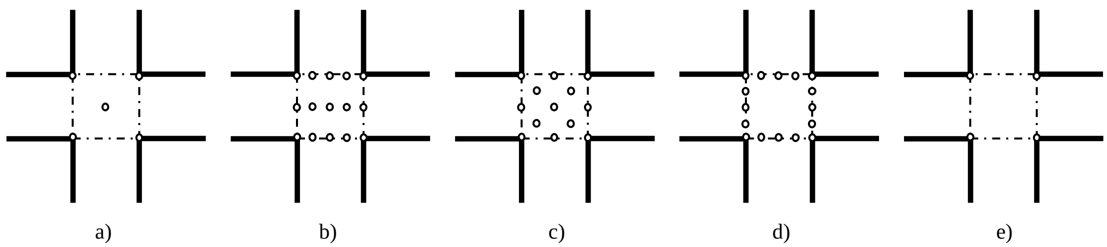
a) *Corner/Middle* – only the corner points and the middle most point(s)

b) *Every Other* – the data collection interval was doubled, resulting in only every other data point collected along each line segment

c) *Checkerboard* – every other data point was used; however, this was staggered for each line

d) *Box* – only the perimeter data points were used

e) *4 Corners* – only the corner data points were used



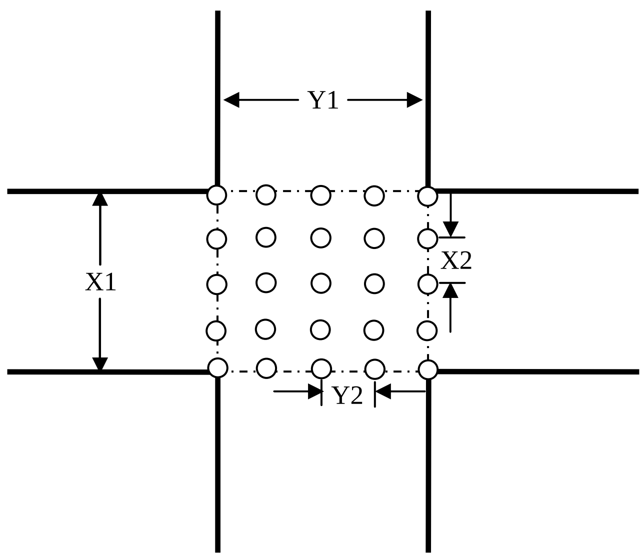
Data collection patterns used.

The various patterns were analyzed in an effort to reduce the amount of data collection points needed. The data from the checkerboard pattern compared very well to the actual average luminance for every collection site. The following table illustrates how each pattern relates to the average illumination for all data points.

Site	All Data	Corner/ Middle	Every Other	Checker-board	Box	4 Corners
1	0.22	0.21	0.25	0.23	0.21	0.10
2	0.36	0.36	0.38	0.39	0.35	0.38
3	0.18	0.18	0.16	0.21	0.18	0.20
4	0.14	0.18	0.16	0.14	0.13	0.09
5	0.61	0.61	0.64	0.63	0.54	0.35
6	0.33	0.56	0.32	0.35	0.36	0.97
7	0.31	0.52	0.33	0.32	0.49	0.91
8	0.52	0.44	0.57	0.53	0.52	0.49
9	1.76	2.30	1.99	1.90	1.83	3.13
10	0.60	0.62	0.63	0.60	0.59	0.60
11	0.53	0.51	0.44	0.55	0.54	0.50
12	0.32	0.35	0.34	0.33	0.33	0.39
13	0.33	0.34	0.33	0.33	0.30	0.29
14	1.02	1.07	0.97	1.02	1.14	1.59
15	1.95	2.66	2.00	1.90	2.35	3.97
16	0.50	0.59	0.55	0.49	0.61	1.14
Average	**0.61**	**0.72**	**0.63**	**0.62**	**0.65**	**0.94**

The number of data points varied based on the size of the intersection and the number of lanes using this data collection method. Additionally, because the collection process was dependent on through lanes, roadway divisions and turning lanes made it difficult to obtain an accurate distribution of the light data at certain intersections. Therefore, it was decided that another methodology should be employed for collecting intersection lighting data. Input was provided by KYTC representatives during a Study Advisory Committee meeting with agreement that a more evenly spaced data collection pattern should be used. Based on the consensus from the meeting, a grid pattern was used.

Data were collected in a grid pattern at equal intervals resulting in grid sizes of 5 by 5 and 7 by 7. The interval lengths were based on the length and width of the data collection boundary. For example, a boundary that is 20 feet by 40 feet would have 25 data points spaced at 5 feet horizontally and 10 feet vertically in the 5 by 5 grid arrangement. The following diagram illustrates this collection methodology.



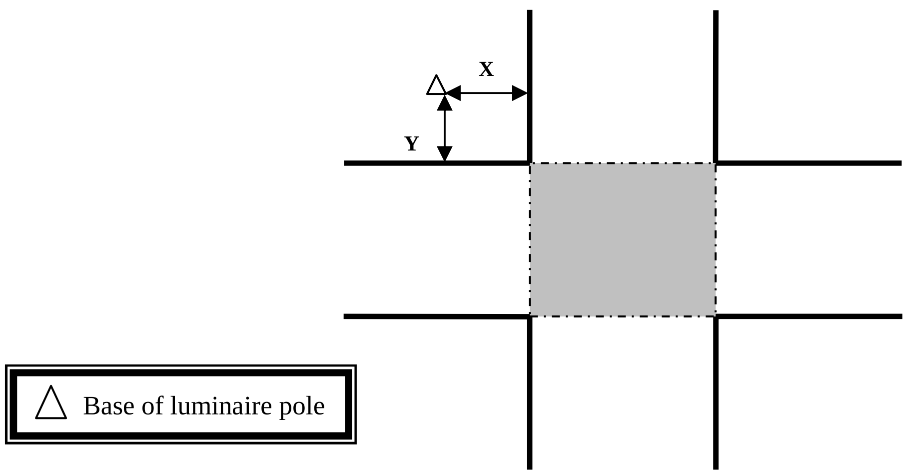
Where Y1 represents the width of the intersection boundary and Y2 is ¼ of this value. Similarly, X1 is the length of the intersection boundary and X2 is ¼ of this value.

A t-test comparing the means was used to determine if the average illuminance was statistically different in the 5 by 5 grid as compared to the 7 by 7. It was determined that, at a 95 percent confidence level, the 5 by 5 grid would be representative of the average luminance for the intersection. The KYTC representatives from the Study Advisory Committee also agreed that 25 data points would be adequate.

Data were collected using the light meter at 4 ¾ feet above the ground beginning at one of the intersection boundary corners. This height was used based on the AASHTO procedure. The following intersection characteristics were collected in addition to 25 light data points:

- Intersection location
- Latitude and longitude
- Data collection date and time
- Intersection type (e.g. rural, tee intersection)
- Number of lanes
- Presence of turning lanes
- Additional comments (e.g. ambient light)
- Number of luminaries
- Luminaire wattage and height
- Intersection boundary height and width

The position of each luminaire was also measured relative to the nearest intersection boundary corner. Two measurements were taken with one distance parallel to the intersection boundary height and one parallel to the intersection boundary width. The following diagram describes this measurement.



Where x and y represent the distances to the nearest boundary corner.

The latitude and longitude were measured using a Magellan SporTrak GPS unit. The luminaire wattage was obtained by observing a label located on the bottom of the light bulb casing. The label identified one-tenth of the wattage of the light bulb. For example, a 100-watt light would have a label showing “10.” The height of the light pole was estimated using triangulation projected on a yardstick. A triangle was created using the data collector’s arm and a yardstick. This triangle was projected onto the height of the light pole at a known distance away from the base of the pole to estimate the height. The data collection form used is shown in Figure 5.

4.4.2 Data Summary

Data were collected at tee- and cross-intersections with either two or four lanes on the major road and with various numbers of luminaires. The average illuminance for the intersection was determined as well as the average/minimum ratio (uniformity). The average value would give the illuminance provided for the area bounded by the intersection boundary. A summary of the data is provided in Table 3. The data summary is organized into five groups: 2-lane tee-intersections, 4-lane tee-intersections, 2-lane cross-intersections, 4-lane cross-intersections, and high mast lighting. Each group is sorted by the average illuminance in ascending order. The data was also organized into groups by number of luminaires and lighting configuration (i.e. quadrant position of the light poles). This data is presented in Table 4 and each group was again sorted by average illuminance in ascending order.

4.4.3 Data Collection Limitations

Several issues made it difficult to obtain consistent illuminance data. The most prominent limitation is ambient light. Several data collection sites had the presence of some form of ambient light near the intersection such as business lighting, parking lot lighting, residential lighting, and moonlight. The effect of such ambient light on the average illumination varied substantially from site to site. Some of these effects are footnoted in Table 4. Another significant cause of inconsistency was the condition of the light bulb. Collections of dirt and insects in the light cover can significantly affect the brightness of the luminare. In addition, the age of the bulb also has a considerable affect on the illumination (9). As the lamp ages, the light output decreases. This is known as Lamp Lumen Depreciation (LLD). These factors were too difficult to accurately quantify. Other sources of inconsistency included the addition of light from traffic signals and flashing beacons within the intersection.

4.4.4 Data Results

The illumination data results are summarized in Tables 3 and 4. When the group averages given in Table 4 are considered, it can be seen that the average luminance for an intersection increases as the number of luminaries increase. However, there was a wide range in average illuminance for intersections within the same group. Comparing the average illuminance with AASHTO guidelines shows the recommended levels at an intersection can be met with a limited number of properly located luminaires. For example, one luminaire placed across from the single approach at a “T-intersection” or two luminaries on diagonal quadrants of a “cross-intersection” were found to meet the guidelines if properly located. The range in the data shows how the various factors can affect the data.

5.0 CONCLUSIONS

1. A procedure was developed to identify spots or sections that have a critical number or rate of nighttime crashes. This procedure can be used to obtain a list of locations to investigate for possible improvements that could include roadway lighting or additional signage or markings to provide warning and delineation of a roadway feature.

2. A large number of the locations identified as having a high nighttime crash rate were rural locations where the nighttime crashes can be addressed with improved delineation (pavement markings and signing).

3. The illumination data show that the AASHTO guidelines (3) can be met with a limited number of properly located luminaires. For example, one luminaire placed across from the single approach at a "T-intersection" or two luminaries on diagonal quadrants of a "cross-intersection" were found to meet the guidelines if properly located.

4. There is a variety of warrants used across the country. Lighting warrants commonly relate to traffic volumes and an existing or potential traffic crash problem. There is no standard crash number or rate used. The procedure previously noted should be used to identify high crash locations. Other locations should be considered where there is a feature that has the potential to result in nighttime crashes.

5. There is an overrepresentation of nighttime crashes compared to nighttime ADT. The higher percentage of crashes during darkness compared with the percentage of volume during this time period shows the higher crash rate at night.

6. Using a limited number of sites, it was shown that nighttime crashes were reduced approximately 45 percent after the addition of roadway lighting at intersections.

7. Even though roadway lighting can increase safety and security, installations should be evaluated to ensure sensitivity to environmental issues such as light trespass and light pollution.

8. In many cases, the cost of roadway lighting can be justified based on reduction in crashes.

6.0 RECOMMENDATIONS

The investigation resulted in the following recommendations for the portion of the KYTC Traffic Guidance Manual dealing with roadway lighting.

1. The interactive nighttime critical rate analysis program should be used to identify high crash sites. Sites with the highest Critical Rate Factors should be evaluated to determine whether lighting or some additional method of delineation should be installed. The procedure in Appendix L describes this process.

2. The warranting conditions specified in the AASHTO report entitled "An Information Guide for Roadway Lighting" should be referenced when determining locations where lighting should be installed. Additional conditions that warrant consideration of roadway lighting include:
    a. rural intersection with traffic signal
    b. rural intersection with raised channelization
    c. high pedestrian volume
    d. railroad crossings with gates or signals
    e. rural intersection in location where fog is a common occurrence
    f. rural intersection with high volume of large trucks pulling from side road (note that additional lighting might be necessary upstream from the intersection to allow the large trucks to attain travel speed while in the lighted area)

3. Given the results of the illumination data, consideration should be given to placing luminaries in the patterns referenced in Appendix G which will allow a reduced number compared to typical installations.

4. A sample of specific types of existing lighting installations should be evaluated to verify that the intersections meet the required levels of average illumination. Furthermore, the surroundings should be measured to insure that the roadway lighting does not unnecessarily contribute to light pollution and light trespass.

7.0 REFERENCES

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8. “Median Mount Lighting: Cost Saving Alternative for Highway Retrofits,” www.holophane.com/school/tech/bc1/htm.

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Figure 1. HOURS OF DARKNESS IN KENTUCKY BY MONTH

*The time interval starts at the hour in the first column. For example, in January the first hour of darkness began at 7:00 PM.

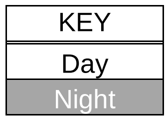


Figure 2. SAMPLE C2 OUTPUT (NIGHTTIME CRASHES/NO ROADWAY LIGHTING 1999-2001)

HD	CO	RT	SU	# CRASHES	BMP	EMP	NK	NI	ADT	RU	NL	MT	FC	Cact	Crate	CRF
8	1	61		4	8.05	8.15	0	1	247	Rural	2	None	7 MajC	14.777	9.047	1.633
8	1	61		5	13.85	14.1	0	1	785	Rural	2	None	7 MajC	5.82	5.229	1.113
8	1	61		3	21.447	21.455	1	3	211	Rural	2	None	6 MA	13.015	9.855	1.321
8	1	76		3	12	12.2	0	1	113	Rural	2	None	8 MinC	24.146	13.994	1.726
8	1	206		6	2.3	2.526	0	3	401	Rural	2	None	7 MajC	13.679	7.092	1.929
8	1	3491		3	0.3	0.4	0	1	325	Rural	2	None	9 Local	8.427	7.859	1.072
8	1	9008		4	49.8	50.1	0	1	882	Rural	4	Unprot	2 PA oth	4.14	2.428	1.706
3	2	101		3	3	3.24	0	0	309	Rural	2	None	7 MajC	8.866	8.063	1.1
7	3	44		3	7.697	7.84	0	3	146	Rural	2	None	7 MajC	18.707	12.058	1.551
7	3	62		3	14.16	14.36	0	2	354	Rural	2	None	7 MajC	7.738	7.532	1.027
7	3	62		4	15.083	15.18	0	2	520	Rural	2	None	7 MajC	7.027	6.272	1.12
7	3	62		6	22.13	22.334	0	2	1122	Rural	2	None	7 MajC	4.885	4.519	1.081
7	3	127		4	2.9	3.13	0	0	517	Rural	2	None	8 MinC	7.071	6.29	1.124
1	4	51		5	1.7	1.9	1	2	404	Rural	2	None	2 PA oth	11.303	7.063	1.6
1	4	60		8	4.97	5.1	0	2	707	Rural	2	None	2 PA oth	10.329	5.466	1.89
3	5	63		3	6.94	7	0	2	333	Rural	2	None	7 MajC	8.224	7.764	1.059
3	5	68		4	5.912	6.03	0	0	480	Rural	2	None	7 MajC	7.617	6.51	1.17
3	5	68		4	6.85	7.013	0	0	480	Rural	2	None	7 MajC	7.617	6.51	1.17
3	5	87		3	4.94	5.11	0	0	148	Rural	2	None	8 MinC	18.483	11.976	1.543
3	5	87		3	10.47	10.7	0	2	148	Rural	2	None	8 MinC	18.483	11.976	1.543
3	5	87		3	11.3	11.35	0	1	148	Rural	2	None	8 MinC	18.483	11.976	1.543
3	5	249		3	11	11.021	1	0	354	Rural	2	None	7 MajC	7.731	7.529	1.027
3	5	740		3	1.6	1.8	0	0	135	Rural	2	None	8 MinC	20.266	12.627	1.605
3	5	839		3	1	1	0	1	168	Rural	2	None	8 MinC	16.306	11.156	1.462
3	5	9008		3	1	1.01	0	0	1388	Rural	4	Unprot	2 PA oth	1.974	1.924	1.026
3	5	9008		3	8.13	8.326	0	1	1388	Rural	4	Unprot	2 PA oth	1.974	1.924	1.026
3	5	9008		3	18.019	18.3	0	0	915	Rural	4	Unprot	2 PA oth	2.996	2.382	1.258
3	5	9008		3	18.9	19	0	1	915	Rural	4	Unprot	2 PA oth	2.996	2.382	1.258
3	5	9065		8	46.88	47.1	0	8	6171	Rural	4	Unprot	1 PA Int	1.184	0.903	1.31
9	6	11		5	6.01	6.28	0	2	383	Rural	2	None	6 MA	11.916	7.246	1.645
9	6	36		3	9.106	9.2	0	1	260	Rural	2	None	7 MajC	10.541	8.812	1.196
9	6	36		3	15.92	16	0	0	267	Rural	2	None	7 MajC	10.249	8.684	1.18
9	6	60		3	0.577	0.78	0	1	193	Rural	2	None	7 MajC	14.198	10.333	1.374
9	6	60		4	5.8	6	0	3	193	Rural	2	None	7 MajC	18.93	10.333	1.832
11	7	72		3	1.2	1.33	0	0	310	Rural	2	None	8 MinC	8.829	8.046	1.097
11	7	221		4	1.8	2	0	2	627	Rural	2	None	7 MajC	5.83	5.765	1.011
6	8	14		4	0.7	1	0	0	362	Rural	2	None	7 MajC	10.088	7.449	1.354
6	8	20		3	0.114	0.3	0	1	219	Rural	2	None	7 MajC	12.517	9.651	1.297
6	8	42		8	3.21	3.44	0	6	639	Rural	2	None	7 MajC	11.434	5.715	2.001
6	8	237		6	3.58	3.846	0	3	1209	Urban	2	None	17 C	4.531	4.012	1.13
6	8	338		4	24.9	25.09	0	0	598	Urban	2	None	17 C	6.113	5.431	1.126
6	8	536		3	7.6	7.73	0	0	219	Rural	2	None	7 MajC	12.508	9.647	1.297
6	8	536		5	10.37	10.58	0	6	745	Urban	2	None	16 MA	6.132	4.918	1.247
6	8	3060		5	2.06	2.28	0	0	687	Urban	2	None	17 C	6.649	5.098	1.304
7	9	353		4	2.94	3.212	0	1	396	Rural	2	None	7 MajC	9.227	7.132	1.294
7	9	460		6	3.32	3.581	0	5	699	Rural	2	None	6 MA	7.839	5.495	1.427
7	9	460		3	15.34	15.52	0	0	356	Rural	2	None	6 MA	7.706	7.517	1.025
9	10	5		5	1.52	1.8	0	6	548	Rural	2	None	7 MajC	8.325	6.12	1.36
9	10	9064		7	183.8	184	0	5	2931	Rural	4	Unprot	1 PA Int	2.181	1.227	1.777
7	11	150		6	1.2	1.41	0	3	393	Rural	2	None	6 MA	13.959	7.162	1.949
6	12	10		3	1	1.3	0	0	90	Rural	2	None	7 MajC	30.562	16.137	1.894
6	12	10		3	2.6	2.878	0	2	90	Rural	2	None	7 MajC	30.562	16.137	1.894

Figure 3. C2 SUMMARY OUTPUT FOR NIGHTTIME CRASHES (NO ROADWAY LIGHTING 1999-2001)

```
******** S P O T ********
 The Length is              .300
 The Critical Number is     3
 All nighttime crashes in KY from 1999 to 2001, unlit

        Total Number of Spots/Sections:        2851
 Number of Spots/Sections with CRF >=1:         782
```

	0.1		0.3		>=0.4	
	R	U	R	U	R	U
1	.17	N/A	.50	N/A	167.	N/A
2	.46	.40	1.38	1.19	460.	397.
3	.30	.69	.90	2.07	297.	678.
4U	.20	.39	.60	1.16	201.	388.
4D	.35	.56	1.05	1.68	351.	561.
INTS	.10	.17	.29	.51	98.	169.
PRK	.12	.17	.35	.50	118.	168.

Total Number of Spots/Sections with a CRF>=1 by County

1)	7	31)	5	61)	10	91)	7
2)	1	32)	4	62)	4	92)	7
3)	5	33)	2	63)	14	93)	4
4)	2	34)	11	64)	0	94)	3
5)	14	35)	0	65)	0	95)	0
6)	5	36)	18	66)	0	96)	7
7)	2	37)	15	67)	6	97)	6
8)	8	38)	1	68)	4	98)	30
9)	3	39)	1	69)	6	99)	1
10)	2	40)	4	70)	5	100)	18
11)	1	41)	18	71)	7	101)	0
12)	10	42)	11	72)	6	102)	2
13)	0	43)	13	73)	30	103)	17
14)	3	44)	1	74)	3	104)	0
15)	16	45)	6	75)	3	105)	13
16)	1	46)	2	76)	8	106)	13
17)	6	47)	11	77)	2	107)	1
18)	6	48)	4	78)	14	108)	4
19)	7	49)	11	79)	14	109)	6
20)	0	50)	3	80)	4	110)	2
21)	7	51)	21	81)	7	111)	2
22)	7	52)	4	82)	3	112)	3
23)	4	53)	1	83)	3	113)	7
24)	13	54)	21	84)	4	114)	19
25)	9	55)	1	85)	3	115)	1
26)	4	56)	5	86)	0	116)	2
27)	0	57)	7	87)	7	117)	7
28)	2	58)	8	88)	2	118)	2
29)	1	59)	14	89)	11	119)	2
30)	14	60)	7	90)	22	120)	4

Total Number of Spots/Sections with a CRF>=1 by Highway District

1)	80
2)	112
3)	53
4)	81
5)	64
6)	86
7)	76
8)	43
9)	59
10)	18
11)	37
12)	73

Figure 4. C2 SUMMARY OUTPUT FOR NIGHTTIME INTERSECTION CRASHES (NO ROADWAY LIGHTING 1999-2001)

```
******** S P O T  ********
 The Length is              .005
 The Critical Number is     2
 All nighttime crashes in KY from 1999 to 2001, unlit, at intersections

        Total Number of Spots/Sections:        232
 Number of Spots/Sections with CRF >=1:        232


               0.1              0.3            >=0.4
           R        U       R        U      R        U
-------------------------------------------------------
     1     .17      N/A     .50      N/A    167.     N/A
     2     .46      .40    1.38     1.19    460.     397.
     3     .30      .69     .90     2.07    297.     678.
    4U     .20      .39     .60     1.16    201.     388.
    4D     .35      .56    1.05     1.68    351.     561.
  INTS     .10      .17     .29      .51     98.     169.
   PRK     .12      .17     .35      .50    118.     168.

Total Number of Spots/Sections with a CRF>=1 by County

 1)    0|     31)    0|     61)    5|      91)    0|
 2)    0|     32)    0|     62)    0|      92)    1|
 3)    0|     33)    1|     63)    9|      93)    1|
 4)    0|     34)    1|     64)    0|      94)    0|
 5)    0|     35)    2|     65)    0|      95)    0|
 6)    1|     36)    3|     66)    0|      96)    0|
 7)    0|     37)    5|     67)    1|      97)    2|
 8)   11|     38)    0|     68)    1|      98)    4|
 9)    0|     39)    0|     69)    1|      99)    0|
10)    3|     40)    1|     70)    0|     100)   10|
11)    0|     41)    2|     71)    1|     101)    0|
12)    1|     42)    6|     72)    0|     102)    2|
13)    4|     43)    0|     73)   16|     103)    3|
14)    1|     44)    0|     74)    3|     104)    0|
15)    6|     45)    1|     75)    0|     105)    2|
16)    0|     46)    0|     76)    7|     106)    5|
17)    0|     47)    3|     77)    0|     107)    0|
18)    6|     48)    0|     78)    1|     108)    2|
19)    8|     49)    0|     79)    5|     109)    1|
20)    0|     50)    0|     80)    0|     110)    0|
21)    0|     51)    2|     81)    2|     111)    1|
22)    2|     52)    1|     82)    3|     112)    0|
23)    0|     53)    0|     83)    0|     113)    0|
24)    1|     54)    0|     84)    0|     114)    5|
25)    1|     55)    0|     85)    0|     115)    1|
26)    0|     56)   42|     86)    0|     116)    1|
27)    0|     57)    7|     87)    1|     117)    0|
28)    0|     58)    0|     88)    0|     118)    4|
29)    0|     59)    2|     89)    0|     119)    0|
30)    3|     60)    0|     90)    4|     120)    0|

Total Number of Spots/Sections with a CRF>=1 by Highway District

 1)   34
 2)    7
 3)    6
 4)   14
 5)   62
 6)   24
 7)   20
 8)   17
 9)   15
10)    7
11)   18
12)    8
```

Figure 5. DATA COLLECTION FORM FOR ILLUMINATION DATA

Location:____________________@_____________________

Date:________________ **Time:______________________**

Class: **Rural** **Urban** **Residential** **Other:________________**

Type: **Cross** **T** **Y** **Other:________________**

# of Lanes:____

Turn Lanes:____

Number of Luminaires:________________________________

Details:____

Lattitude/Longitude:___________________________________

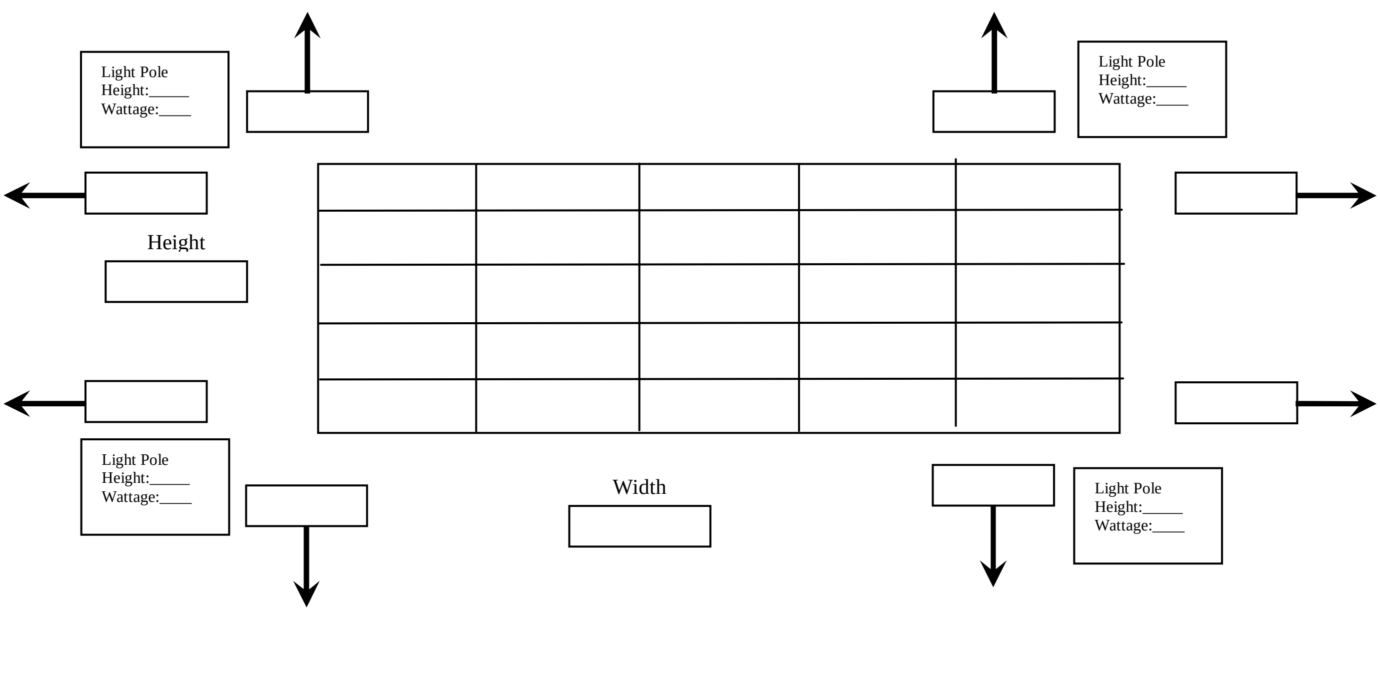
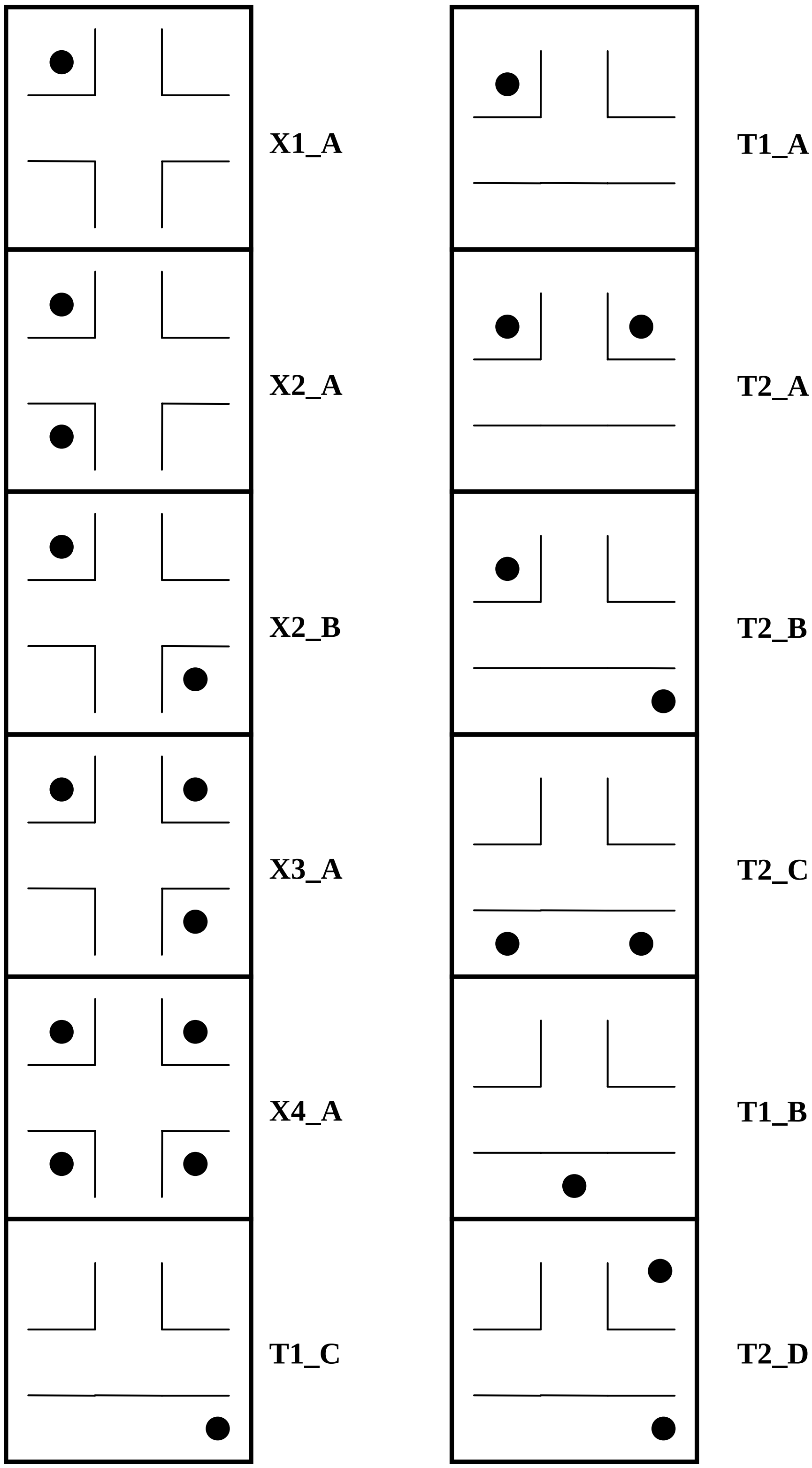


Figure 6. LIGHTING POLE CONFIGURATION PATTERNS



Where X=Cross, T=Tee, and the number represents the number of luminaires.

TABLE 1. SUMMARY OF ALL CRASHES FOR DAYTIME AND NIGHTTIME (1999-2001)

VARIABLE	CATEGORY	DAYLIGHT	DARKNESS*
Severity	Fatal	0.39	1.45
	Injury	24.91	32.30
Day of Week	Weekend	21.48	35.21
Number of Vehicles	One	16.86	66.99
Road Surface Conditions	Snow/Ice	3.53	9.10
Road Character	Curve	19.16	36.00
	Straight	80.84	64.00
Month	December - February	20.62	32.75
	March - May	26.88	19.55
	June - August	27.70	16.54
	September - November	24.80	31.16
Directional Analysis	Intersection	34.93	13.76
	Non-Intersection		
	Rear End in Traffic Lane	15.50	5.09
	Shoulder/Parked Vehicle	0.90	2.01
	Same Direction Sideswipe	5.28	2.72
	Entrance	6.80	2.71
	Fixed Object	7.76	23.15
	Ran Off Roadway	5.85	19.43
	Animal	0.99	17.84
Type Accident	Deer	0.64	12.93
1st Event	Other Vehicle	79.87	30.39
	Fixed Object	13.02	40.54
	Non-Collision	2.40	6.10
Counties with	Jefferson	22.27	8.80
Highest Number	Fayette	9.81	2.60
	Kenton	4.06	2.03
Contributing Factors	Environmental		
(Percent of all crashes)	Animal Action	1.27	18.66
	Road Construction	0.97	0.49
	Debris	0.44	1.47
	Defective Shoulder	0.32	0.53
	Slippery Surface	12.99	17.57
	View Limited	4.12	2.60
	Water Pooling	1.04	1.65
Contributing Factors	Human		
(Percent of all crashes, continued)	Alcohol	1.84	14.05
	Disregard Traffic Control	3.52	1.00
	Distraction	3.01	2.16
	Drug	0.45	1.58
	Exceeded Speed Limit	1.22	3.03
	Failed to Yield	15.58	4.90
	Fatigue	0.22	0.45
	Fell Asleep	0.81	2.76
	Following too Close	7.04	1.41
	Inattention	41.11	18.42
	Misjudge Clearance	3.22	1.58
	Not Under Proper Control	4.90	7.05
	Over-correcting	1.92	4.53
	Too Fast for Conditions	5.09	9.59
	Weaving in Traffic	0.27	0.15
	Vehicular Factor	2.83	2.62

*Darkness category includes crashes where lighting was present but turned off

TABLE 2. SUMMARY OF ALL FATAL CRASHES FOR DAYTIME AND NIGHTTIME (1999-2001)

VARIABLE	CATEGORY	DAYLIGHT	DARKNESS*
Day of Week	Weekend	29.32	38.03
Number of Vehicles	One	41.62	68.80
Road Surface Conditions	Dry	78.48	83.26
Road Character	Curve	39.53	39.74
	Straight	60.47	60.26
Month	December - February	17.02	24.36
	March - May	26.18	23.50
	June - August	28.53	22.65
	September - November	28.27	29.49
Directional Analysis	Intersection	22.51	7.69
	Non-Intersection		
	Rear End in Traffic Lane	2.62	1.28
	Shoulder/Parked Vehicle	1.57	1.71
	Head-on/Opposite Dir.	12.30	7.69
	Same Direction Sideswipe	1.31	0.43
	Entrance	7.85	4.27
	Pedestrian	3.66	6.41
	Fixed Object	25.39	35.90
	Ran Off Roadway	13.61	28.63
Type Accident	Other Vehicle	50.00	23.08
1st Event	Pedestrian	3.40	5.56
	Fixed Object	36.65	60.26
	Non-Collision	7.07	8.12
Contributing Factors	Environmental		
(Percent of all crashes)	Road Construction	3.66	3.32
	Improperly Parked	0.79	1.00
	Slippery Surface	12.57	12.29
	View Limited	3.66	3.65
	Water Pooling	2.36	0.66
	Human		
	Alcohol	12.57	32.89
	Disregard Traffic Control	5.24	3.65
	Distraction	1.83	1.66
	Drug	1.05	2.33
	Exceeded Speed Limit	12.04	13.29
	Failed to Yield	17.02	9.30
	Fatigue	0.79	1.00
	Fell Asleep	2.88	3.99
	Inattention	23.30	17.61
	Over-correcting	11.78	6.98
	Too Fast for Conditions	8.38	9.97
	Vehicular Factors	4.97	5.32

*Darkness category includes crashes where lighting was present but turned off

TABLE 3. ILLUMINATION DATA ORDERED BY INTERSECTION TYPE, NUMBER OF LANES, AND AVERAGE ILLUMINATION

Description	Location	Average Illuminace	Uniformity	Class	ADT	Size	Average Height	Total Watt
Cross (X) 2 Lanes 1 Light	KY 169 @ KY 1267	0.18	3.10	Rural	2620	925	30	250
Group Average =0.51	KY 169 @ N.Cental	0.23	3.90	Urban	3830	1302	32	250
	Ironworks @ W. Horeb	0.24	20.08	Rural	2900	1560	33	100
	Middlesex @ Westerfield Way	0.25	13.05	Residential	-	2923	22	50
	Severn Way @ Westerfield Way	0.25	4.79	Residential	-	1760	22	50
	Westerfield @ Ark Royal	0.27	8.30	Residential	-	2035	24	50
	Russell Cave @ Hoffman	0.36	3.82	Rural	4680	1875	33	100
	Tulsa Dr. @ Burbank	0.58	9.73	Residential	-	2294	24	100
	KY 29 @ W. Morrison	1.16	4.15	Urban	5780	2937	30	200
	KY 29 @ KY 1268	1.57	4.32	Urban	4080	1620	30	200
Cross (X) 2 Lanes 2 Light	Fergeson @ Greenwich	0.21	5.63	Rural		3404	25	140
Group Average =0.59	Ironworks @ Newtown	0.33	2.93	Rural	6640	2925	33	200
	US 60 @ N. Cleveland	0.48	3.12	Rural	15700	4389	30	200
	KY 1973 @ KY 1927	0.72	2.05	Rural	2770	1463	34	200
	KY 29 @ College (KY 3433)	0.73	2.50	Urban	6320	3569	30	400
	Ironworks @ Russell Cave	0.75	2.05	Rural	8740	2403	34	200
	Muir Station @ Bryan Station Rd.	0.88	3.42	Rural	1570	1600	32	100
Cross (X) 4 Lanes 1 Light	KY 686 @ Kroger	0.69	2.80	Urban	23400	8211	30	400
Group Average =0.89	KY 3487 @ US 62	1.09	15.30	Rural	13600	5625	42	250
Cross (X) 4 Lanes 2 Light	KY 3487 @ Toyota Gate #3	0.86	11.62	Rural	13600	21252	42	500
Group Average =1.36	US 27/68 @ Reinhold St.	1.12	9.19	Urban	15900	5865	40	250
	KY 686 @Brookmede Dr.	1.42	5.38	Urban	23400	6930	30	800
	US 460 B @ US 460	1.58	26.69	Rural	20400	14231	35	800
	KY 686 @ US 60	1.85	6.22	Urban	23400	7800	30	800
Cross (X) 4 Lanes 3 Light	KY 686 @ US 460	0.96	6.07	Urban	23400	13916	30	1200
Group Average =1.14	KY 686 @ KY 713	1.33	9.50	Urban	23400	8280	31	1200
Cross (X) 4 Lanes 4 Light	KY 686 @ KY 11	1.90	8.22	Urban	23400	14934	30	1600
Group Average =2.77	US 460 B @ US 62	3.65	7.81	Rural	21000	12212	32	1600
Cross (X) 4 Lanes High Mast	KY 80 @ KY 160	1.38	1.92	Rural	7700	9804	120	6000
Tee (T) 2 Lanes 1 Light	US 60 @ KY 1425 (Man O' War)	0.19	3.33	Rural	13300	5336	30	100
Group Average =0.43	Hill N Dale @ Yuma Ct.	0.27	3.70	Residential	-	2090	30	70
	US 25/421 @ KY 1975	0.27	2.95	Rural	3850	1984	35	100
	Ironworks @ Kenny	0.28	92.00	Rural	1910	1050	31	100
	Topeka Rd @ Wichita	0.28	13.38	Residential		2604	24	50
	Yarnellton @ Spurr	0.35	26.92	Rural	855	1378	34	100
	Tates Creek @ KY 1975	0.36	4.65	Rural	1150	1210	30	250
	Lamont Dr. @ Lamont Ct	0.38	9.32	Residential	-	1922	24	50
	Severn @ Black Arrow Ct	0.41	7.94	Residential	-	1581	22	50
	US 60 @ Royster	0.54	2.83	Rural	13300	1890	30	100
	US 60 @ Haley	0.63	2.91	Rural	15300	4002	30	100
	US 60 @ Walnut Grove	0.77	2.40	Rural	13300	2133	26	100
	Parker's Mill @ Bowman	0.86	16.21	Rural	937	1160	27	70
Tee (T) 2 Lanes 2 Light	US 60 @ KY 1923 (Combs Ferry)	0.42	3.73	Rural	13300	2025	30	200
Group Average =0.59	Russell Cave @ Greenwich	0.51	5.41	Rural	4680	1800	30	140
	US 25 @ Evans Mill Rd	0.55	91.83	Rural	4120	2704	35	200
	Parker's Mill @ Dedman	0.74	4.81	Rural	522	1846	23	140
	Russell Cave @ Hughes	0.75	62.42	Rural	4680	1512	33	200
Tee (T) 4 Lanes 1 Light	US 27 @ US 460	0.248	19.076	Rural	16400	13230	35	200
Group Average =0.45	KY 3487 @ Delaplain	0.542	3.132	Rural	13600	3560	42	250
	KY 686 @ Walmart	0.552	8.238	Urban	23400	7276	30	400

TABLE 4. ILLUMINATION DATA ORDERED BY NUMBER OF LUMINAIRES, LIGHTING CONFIGURATION AND AVERAGE ILLUMINATION

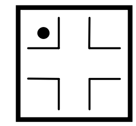
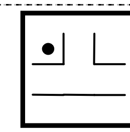
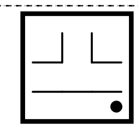
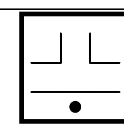
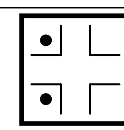
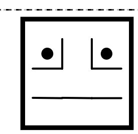
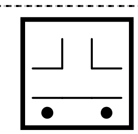
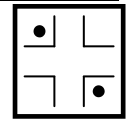
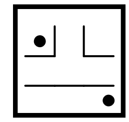
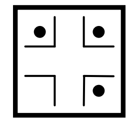
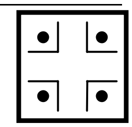
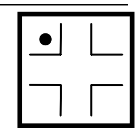
Group Average*	Location	Average Illuminance	Uniformity	Class	ADT	Size	Average Height	Total Watt	Configuration**	
0.48	KY 169 @ KY 1267	0.18[A]	3.10	Rural	2620	925	30	250	X1_A	
	KY 169 @ N.Cental	0.23[A]	3.90	Urban	3830	1302	32	250	X1_A	
	Ironworks @ W. Horeb	0.24[B]	20.08	Rural	2900	1560	33	100	X1_A	
	Middlesex @ Westerfield Way	0.25	13.05	Residential	-	2923	22	50	X1_A	
	Severn Way @ Westerfield Way	0.25	4.79	Residential	-	1760	22	50	X1_A	
	Westerfield @ Ark Royal	0.27	8.30	Residential	-	2035	24	50	X1_A	
	Russell Cave @ Hoffman	0.36[C]	3.82	Rural	4680	1875	33	100	X1_A	
	Tulsa Dr. @ Burbank	0.58	9.73	Residential	-	2294	24	100	X1_A	
	KY 686 @ Kroger	0.69	2.80	Urban	23400	8211	30	400	X1_A	
	KY 3487 @ US 62	1.09	15.30	Rural	13600	5625	42	250	X1_A	
	KY 29 @ W. Morrison	1.16	4.15	Urban	5780	2937	30	200	X1_A	
	KY 29 @ KY 1268	1.57	4.32	Urban	4080	1620	30	200	X1_A	
	Hill N Dale @ Yuma Ct.	0.27[D]	3.70	Residential	-	2090	30	70	T1_A	
	US 25/421 @ KY 1975	0.27	2.95	Rural	3850	1984	35	100	T1_A	
	Yarnellton @ Spurr	0.35	26.92	Rural	855	1378	34	100	T1_A	
	Tates Creek @ KY 1975	0.36[A]	4.65	Rural	1150	1210	30	250	T1_A	
	US 60 @ Royster	0.54	2.83	Rural	13300	1890	30	100	T1_A	
	KY 3487 @ Delaplain	0.54	3.13	Rural	13600	3560	42	250	T1_A	
	KY 686 @ Walmart	0.55	8.24	Urban	23400	7276	30	400	T1_A	
	US 60 @ KY 1425 (Man O' War)	0.19	3.33	Rural	13300	5336	30	100	T1_C	
	US 27 @ US 460	0.25[E]	19.08	Rural	16400	13230	35	200	T1_C	
	Ironworks @ Kenny	0.28	92.00	Rural	1910	1050	31	100	T1_C	
	Topeka Rd @ Wichita	0.28	13.38	Residential		2604	24	50	T1_C	
	Parker's Mill @ Bowman	0.86	16.21	Rural	937	1160	27	70	T1_C	
0.55	Lamont Dr. @ Lamont Ct	0.38	9.32	Residential	-	1922	24	50	T1_B	
	Severn @ Black Arrow Ct	0.41	7.94	Residential	-	1581	22	50	T1_B	
	US 60 @ Haley	0.63	2.91	Rural	15300	4002	30	100	T1_B	
	US 60 @ Walnut Grove	0.77	2.40	Rural	13300	2133	26	100	T1_B	
0.95	US 60 @ N. Cleveland	0.48[DE]	3.12	Rural	15700	4389	30	200	X2_A	
	KY 29 @ College (KY 3433)	0.73	2.50	Urban	6320	3569	30	400	X2_A	
	Muir Station @ Bryan Station Rd.	0.88	3.42	Rural	1570	1600	32	100	X2_A	
	KY 3487 @ Toyota Gate #3	0.86	11.62	Rural	13600	21252	42	500	X2_A	
	US 27/68 @ Reinhold St.	1.12	9.19	Urban	15900	5865	40	250	X2_A	
	KY 686 @Brookmede Dr.	1.42	5.38	Urban	23400	6930	30	800	X2_A	
	US 460 B @ US 460	1.58	26.69	Rural	20400	14231	35	800	X2_A	
	KY 686 @ US 60	1.85	6.22	Urban	23400	7800	30	800	X2_A	
	Parker's Mill @ Dedman	0.74	4.81	Rural	522	1846	23	140	T2_A	
	Russell Cave @ Hughes	0.75	62.42	Rural	4680	1512	33	200	T2_A	
	US 60 @ KY 1923 (Combs Ferry)	0.42	3.73	Rural	13300	2025	30	200	T2_C	
	US 25 @ Evans Mill Rd	0.55[B]	91.83	Rural	4120	2704	35	200	T2_C	

TABLE 4. ILLUMINATION DATA ORDERED BY NUMBER OF LUMINAIRES, LIGHTING CONFIGURATION AND AVERAGE ILLUMINATION (continued)

Group Average*	Location	Average Illuminance	Uniformity	Class	ADT	Size	Average Height	Total Watt	Configuration**	
0.50	Fergeson @ Greenwich	0.21	5.63	Rural		3404	25	140	X2_B	
	Ironworks @ Newtown	0.33[D]	2.93	Rural	6640	2925	33	200	X2_B	
	KY 1973 @ KY 1927	0.72	2.05	Rural	2770	1463	34	200	X2_B	
	Ironworks @ Russell Cave	0.75	2.05	Rural	8740	2403	34	200	X2_B	
	Russell Cave @ Greenwich	0.51[D]	5.41	Rural	4680	1800	30	140	T2_B	
1.14	KY 686 @ US 460	0.96	6.07	Urban	23400	13916	30	1200	X3_A	
	KY 686 @ KY 713	1.33	9.50	Urban	23400	8280	31	1200	X3_A	
2.77	KY 686 @ KY 11	1.90	8.22	Urban	23400	14934	30	1600	X4_A	
	US 460 B @ US 62	3.65	7.81	Rural	21000	12212	32	1600	X4_A	
1.38 (high mast)	KY 80 @ KY 160	1.38	1.92	Rural	7700	9804	120	6000	X1_A	

* Group averages are comprised of all configurations with the same lighting placement (e.g. configurations X2_B and T2_B)
**Configuration codes refer to diagrams in Figure 6.
[A] Light bulb is not comparable to typical fixtures
[B] Lighting dispersion is not uniformly distributed
[C] Light bulb is positioned higher than normal
[D] Light pole is positioned further away than normal
[E] Intersection area is larger than normal
[F] Light bulb has a lower wattage than normal

APPENDIX A. SURVEY FORM

Highway Lighting Survey Form
January 30, 2002

1. **Do you have specific warrants for the placement of lighting (other than that given by AASHTO in "An Informational Guide for Roadway Lighting")?**

   Yes If yes, please provide a copy or summary. **No**

2. **Do you have guidelines for the "average maintained illuminance" to be provided by the lighting other than that given in the AASHTO publication?**

   Yes If yes, please provide a copy of the guidelines. **No**

3. **Do you have guidelines for the design of lighting installations (number and placement of luminaries) to achieve the desired illuminance?**

   Yes If yes, please provide a copy of the guidelines. **No**

4. **Has your state conducted any before and after studies to determine the benefits and costs associated with lighting?**

   Yes If yes, what results have been obtained? **No**
   (crashes, environmental effects, etc.)
   Please provide a copy of the documented results, if available.

____

____

5. **Additional Comments.**

____

____

____

Name_______________________________________
Agency_____________________________________
PhoneNumber________________________________
Email______________________________________

Thank you for your assistance.

Send responses to:

Monica Barrett
Kentucky Transportation Center
240 Raymond Building
Lexington, KY 40506-0281
(859) 257-4513 x256
(859) 257-1815 (fax)
mbarrett@engr.uky.edu

APPENDIX B. AASHTO LIGHTING WARRANTS

AASHTO Warrants

Continuous Freeway Lighting

- On sections in and near cities where the current ADT is 30,000 or more
- On sections where three or more successive interchanges are located with an average spacing of 1 ½ miles or less, and adjacent areas outside the right-of-way are substantially urban in character
- For a length of two or more miles, the freeway passes through suburban or urban area in which one or more of the following conditions exists:
  - local traffic operates on a street grid having street lights with parts visible from freeway
  - freeway passes through development with some parts lighted
  - cross streets (with some ramps) occur with an average spacing of ½ mile or less and are lighted
  - freeway cross section elements are below desirable standards
- On sections where the ratio of night to day accident rate is at least 2.0 or higher than the statewide average for unlighted similar sections

Complete Interchange Lighting

- The total current ADT ramp traffic entering and leaving the freeway exceeds 10,000 for urban; 8,000 for suburban; or 5,000 for rural conditions
- The current ADT on crossroad exceeds 10,000 for urban; 8,000 for suburban; or 5,000 for rural conditions
- At locations located in the immediate vicinity of the interchange where existing development areas are lighted or where the crossroad approach legs are lighted for ½ mile or more on each side of the interchange
- On sections where the ratio of night to day accident rate within the interchange area is at least 1.5 or higher than the statewide average for unlighted similar sections

Partial Interchange Lighting

- The total current ADT ramp traffic entering and leaving the freeway exceeds 5,000 for urban; 3,000 for suburban; or 1,000 for rural conditions
- The current ADT on freeway through traffic lanes exceeds 25,000 for urban; 20,000 for suburban; or 10,000 for rural conditions
- On sections where the ratio of night to day accident rate within the interchange area is at least 1.25 or higher than the statewide average for unlighted similar sections

Street and Highway Lighting (general)

- On sections where the ratio of night to day accident rate is higher than the statewide average for unlighted similar sections
- Respective governmental agencies concur that lighting is needed
- Locations where severe or unusual weather or atmospheric conditions exist
- Hazardous locations on rural highways

APPENDIX C.   NCHRP 152 WARRANTS

NCHRP 152 - Table 13

Classification for Noncontrolled Access Facility Lighting

Classification Factor	Rating 1	2	3	4	5	Unlit Weight (A)	Lighted Weight (B)	Diff (A-B)	Score Rating x(A-B)
Geometric Factors									
No. of Lanes	4 or less	-	6	-	8 or more	1.0	0.8	0.2	
Lane Width	>12'	12'	11'	10'	<10'	3.0	2.5	0.5	
Median openings per mile	< 4.0 or one way operation	4.0-8.0	8.1-12.0	12.0-15.0	>15.0 or no access control	5.0	3.0	2.0	
Curb Cuts	<10%	10-20%	20-30%	30-40%	>40%	5.0	3.0	2.0	
Curves	<3.0°	3.1-6.0°	6.1-8.0°	8.1-10.0°	>10.0°	13.0	5.0	8.0	
Grades	<3%	3.0-3.9%	4.0-4.9%	5.0-6.9%	7%or more	3.2	2.8	0.4	
Sight Distance	>700'	500-700'	300-500'	200-300'	<200'	2.0	1.8	0.2	
Parking	prohibited both sides	loading zones	off-peak only	permitted one side	permitted both sides	0.2	0.1	0.1	
						Geometric Total			
Operational Factors									
Signals	all major intersections signalized	substantial majority of intersections signalized	most major intersections signalized	about half the intersection signalized	frequent non-signalized interstions	3.0	2.8	0.2	
Left turn lane	all major intersections or one way operation	substantial majority of intersections	most major intersections	about half the major intersections	infrequent turn bays or undivided streets	5.0	4.0	1.0	
Median Width	30'	20-30'	10-20'	4-10'	0-4'	1.0	0.5	0.5	
Operating Speed	25 or less	30	35	40	45 or greater	1.0	0.2	0.8	
Pedestrian traffic at night (peds/mi)	very few or none	0-50	50-100	100-200	>200	1.5	0.5	1.0	
						Operational Total			
Environmental Factors									
% Development	0	0-30%	30-60%	60-90%	100.00%	0.5	0.3	0.2	
Predominant Type Development	undeveloped or bakup design	residential	half-residential and/or commercial	industrial or commercial	strip industrial or commercial	0.5	0.3	0.2	
Setback Distance	>200'	150-200'	100-150'	50-100'	<50'	0.5	0.3	0.2	
Advertising or Area Lighting	none	0-40%	40-60%	60-80%	essentially continuous	3.0	1.0	2.0	
Raised Curb Median	none	continuous	at all intersections	at signalized intersections	a few locations	1.0	0.5	0.5	
Crime Rate	extremely low	lower than city aver.	city aver.	higher than city aver.	extremely high	1.0	0.5	0.5	
						Environmental Total			
Accidents									
Ratio of night to day accident rates	<1.0	1.0-1.2	1.2-1.5	1.5-2.0	2	10.0	2.0	8.0	
						Accident Total			

*Continuous lighting warranted

Geometric Total	________	
Operational Total	________	
Environmental Total	________	
Accident Total	________	
Sum	________	Points
Warranting Condition	85 points	

NCHRP 152 - Table 14

Classification for Intersection Lighting

Classification Factor	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5	Unlit Weight (A)	Lighted Weight (B)	Diff (A-B)	Score Rating x(A-B)
Geometric Factors									
Number of legs	-	3	4	5	6 or more (including traffic circles)	3.0	2.5	0.5	________
Approach lane width	>12'	12'	11'	10'	<10'	3.0	2.5	0.5	________
Channelization	no turn lanes	left turn lanes on major legs	left turn lanes on all legs, right turn lanes on major	left and right turn lanes on major legs	left and right turn lanes on all legs	2.0	1.0	1.0	________
Approach Sight Distance	>700'	500-700'	300-500'	200-300'	<200'	2.0	1.8	0.2	________
Grades on Approach Streets	<3%	3.0-3.9%	4.0-4.9%	5.0-6.9%	7% or more	3.2	2.8	0.4	________
Curvature on Approach Legs	<3.0°	3.0-6.0°	6.1-8.0°	8.1-10.0°	>10°	13.0	5.0	8.0	________
Parking in Vicinity	prohibited both sides	loading zones only	off-peak only	permitted one-side only	permitted both sides	0.2	0.1	0.1	________
						Geometric Total			________
Operational Factors									
Operating Speed on Approach Legs	25 mph or less	30 mph	35 mph	40 mph	45 mph or greater	1.0	0.2	0.8	________
Type of Control	all phases signalized (incl. Turn lane)	left turn lane signal control	through traffic signal control only	4-way stop control	stop control to minor legs or no control	3.0	2.7	0.3	________
Channelization	left and right signal control	left and right turn lane signal control on major legs	left turn lane signal control on all legs	left turn lane signal control on major legs	no turn lane control	3.0	2.0	1.0	________
Level of Service (Load Factor)	A(0.0)	B(0-0.1)	C(0.1-0.3)	D(0.3-0.7)	E(0.7-1.0)	1.0	0.2	0.8	________
Pedestrian Vol. (ped/hr crossing)	very few or none	0-50	50-100	100-200	>200	1.5	0.5	1.0	________
						Operational Total			________
Environmental Factors									
Percent Adjacent Development	0	0-30%	30-60%	60-90%	100%	0.5	0.3	0.2	________
Predominant Development near Intersection	undeveloped	residential	50% residential - 50% industrial or commercial	industrial or commercial	strip industrial or commercial (no circuity)	0.5	0.3	0.2	________
Lighting in immediate vicinity	none	0-40%	40-60%	60-80%	essentially continuous	3.0	1.5	1.5	________
Crime Rate	extremely low	lower than city aver.	city aver.	higher than city aver.	extremely high	1.0	0.5	0.5	________
						Environmental Total			________
Accidents									
Ratio of night to day accident rates	1	1.0-1.2	1.2-1.5	1.5-2.0	2.0*	10.0	2.0	8.0	________
						Accident Total			________

*Intersection lighting warranted

Geometric Total ________
Operational Total ________
Environmental Total ________
Accident Total ________
Sum ________ Points

Warranting Condition = 75 points

NCHRP 152 - Table 15

Classification for Controlled-Access Facility (Freeway) Lighting

Classification Factor	Rating 1	2	3	4	5	Unlit Weight (A)	Lighted Weight (B)	Diff (A-B)	Score Rating x(A-B)
Geometric Factors									
No. of Lanes	4	-	6	-	=8	1.0	0.8	0.2	______
Lane Width	>12'	12'	11'	10'	=9	3.0	2.5	0.5	______
Median Width	>40'	24-39'	12-23'	4-11'	0-3'	1.0	0.5	0.5	______
Shoulders	10'	8'	6'	4'	0'	1.0	0.5	0.5	______
Slopes	=8:1	6:1	4:1	3:1	2:1	1.0	0.5	0.5	______
Curves	0-½°	½-1°	1-2°	2-3°	3-4°	13.0	5.0	8.0	______
Grades	<3%	3-3.9%	4-4.9%	5-6.9%	>7%	3.2	2.8	0.4	______
Interchange Freq.	4 mi.	3 mi.	2 mi.	1 mi.	<1mi.	4.0	1.0	3.0	______
						Geometric Total			______
Operational Factors									
Level of Service (any dark hour)	A	B	C	D	E	6.0	1.0	5.0	______
						Operational Total			______
Environmental Factors									
% Development	0%	25%	50%	75%	100%	3.5	0.5	3.0	______
Offset to Develop	200'	150'	100'	50'	<50'	3.5	0.5	3.0	______
						Environmental Total			______
Accidents									
Ratio of night to day accident rates	1	1-1.2	1.2-1.5	1.5-2.0	2.0*	10.0	2.0	8.0	______
						Accident Total			______

* Continuous lighting warranted

Geometric Total	______	
Operational Total	______	
Environmental Total	______	
Accident Total	______	
Sum	______	Points
Warranting Condition	95 points	

NCHRP 152 - Table 16

Classification for Interchange Lighting

Classification Factor	Rating 1	2	3	4	5	Unlit Weight (A)	Lighted Weight (B)	Diff (A-B)	Score Rating x(A-B)
Geometric Factors									
Ramp Types	Direct	Diamond	Button Hooks Cloverleaf	Trumpet	Scissors and left side	2.0	1.0	1.0	______
Cross-Road Channelization	none	-	continuous	-	at interchange intersections	2.0	1.0	1.0	______
Frontage Roads	none	-	one-way	-	two-way	1.5	1.0	0.5	______
Freeway Lane Widths	>12	12	11	10	<10	3.0	2.5	0.5	______
Freeway Median Widths	>40	34-40	12-24	4-12	<4	1.0	0.5	0.5	______
No Freeway Lanes	4 or less	-	6	-	8 or more	1.0	0.8	0.2	______
Main Line Curves	<½°	1-2°	2-3°	3-4°	>4°	13.0	5.0	8.0	______
Grades	3%	3-3.9%	4-4.9%	5-6.9%	7% or more	3.2	2.8	0.4	______
Sight Dist. Cross Road Intersection	>1000'	700-1000'	500-700'	400-500'	<400'	2.0	1.8	0.2	______
						Geometric Total			______
Operational Factors									
Level of Serice (any dark hour)	A	B	C	D	E	6.0	1.0	5.0	______
						Operational Total			______
Environmental Factors									
% Development	none	1 quad	2 quad	3 quad	4 quad	2.0	0.5	1.5	______
Set-Back Distance	>200'	150-200'	100-150'	50-100'	<50'	0.5	0.3	0.2	______
Cross-Road Approach Lighting	none	-	partial	-	complete	3.0	2.0	1.0	______
Freeway Lighting	none	-	interchanges only	-	continuous	5.0	3.0	2.0	______
						Environmental Total			______
Accidents									
Rate of night to day accident rates	<1.0	1.0-1.2	1.2-1.5	1.5-2.0	>2.0*	10.0	2.0	8.0	______
						Accident Total			______

*Complete lighting warranted

Geometric Total	______	
Operational Total	______	
Environmental Total	______	
Accident Total	______	
Sum	______	Points

Complete lighting warranting condition	90 points
Partial lighting warranting condition	60 points

APPENDIX D. SURVEY RESPONSES

	Do you have specific warrants for the placement of lighting (other than that given by AASHTO in "An Information Guide for Roadway Lighting")?		Do you have guidelines for the "average maintained illuminance" to be provided by the lighting other than that given in the AASHTO publication?		Do you have guidelines for the design of lighting installations (number and placement of luminaries) to achieve the desired illuminance?		Has your state conducted any before and after studies to determine the benefits and costs associated with lighting?	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Alabama		X	X			X		X
Alaska		X		X		X		X
Arizona		X		X		X		X
Arkansas		X		X		X		X
California*	X		X		X			X
Florida*		X		X		X		X
Hawaii		X		X		X		X
Idaho		X		X		X		X
Illinois	X		X		X			X
Indiana	X		X		X			X
Iowa	X			X		X		X
Kansas	X			X	X			X
Maryland		X	X			X		X
Massachusetts		X		X		X		X
Michigan		X		X		X	X	
Minnesota	X		X		X		X	
Mississippi		X		X		X		X
Missouri	X		X		X			X
Montana		X		X	X			X
Nevada		X		X		X		X
New Hampshire		X		X		X		X
New Jersey	X		X		X			X
New York	X			X		X		X
North Carolina	X			X	X			X
North Dakota	X			X		X		X
Ohio		X		X		X		X
Oklahoma	X		X			X		X
Oregon*		X		X		X		X
Pennsylvania		X		X		X		X
Rhode Island		X		X		X		X
South Carolina		X		X		X		X
Tennessee		X		X		X		X
Texas		X		X		X		X
Washington	X		X		X		X	
West Virginia		X		X		X		X
Wyoming	X			X		X		X

*Information from Internet

APPENDIX E.   STATES' LIGHTING WARRANTS

STATE	SUMMARY (other than AASHTO)
Alabama	ANSI “Roadway Lighting” RP-8-00
Alaska	No
Arizona	No
Arkansas	No
California	1. Freeway Interchange a. Total sum of ADT ramp volume for all four ramps exceeds 5,000 for urban, 3,000 for suburban, and 1,000 for rural areas b. Freeway ADT exceeds 25,000 for urban, 20,000 for suburban, and 10,000 for rural areas 2. Intersection a. Traffic signal warrant satisfied for single hour during darkness b. 4 or more nighttime accidents in 12 months or 6 or more in 24 months c. Traffic signal or flashing beacon is installed d. Confusing or unsatisfactory condition due to sight distance, channelization, or curvature e. New intersection - if above warrants will be met within 5 years of opening 3. Railroad Grade Crossing a. Substantial amount of railroad nighttime operation
Florida	No
Hawaii	No
Idaho	No
Illinois	1. Freeway - use AASHTO 2. Other than freeways consider the following: a. Raised median b. Major urban arterial c. Rural intersections if one of the following conditions exist: • 2.4 or more accidents per million vehicles in 3 consecutive years • 2.0 or more accidents per million vehicles per year and 4.0 or more accidents per year in 3 consecutive years • 3.0 or more accidents per million vehicles per year and 7.0 or more accidents per year in 2 consecutive years

- Traffic signal and 5 or more nighttime accidents in a year and day-to-night accident ratio under 2
- Substantial nighttime pedestrian volume
- Less than desirable alignment on intersection approaches
- Complex turning maneuvers
- Commercial development that causes high nighttime traffic
- Distracting illumination from adjacent development
- Fog or smog in the area

d. High conflict locations
e. Complex roadway geometry
f. Night-to-day accident ratio higher than statewide average
g. Local agency needs

Indiana	Highway Lighting Accident Warrant Analysis worksheet
Iowa	1. Rural Intersections a. ADT for entering vehicles is 3,500 and intersection is channelized, "T", or a change in direction of the major route b. Night-to-day accident ratio 2.0 or greater with a minimum of 3 nighttime accidents in 12-month period c. Lighted development exists that is affecting operations exists adjacent to the intersection d. Motorists experiencing operational problems that may be reduced by lighting e. Value of "c" exceeds 3,000 points in formula considering sight distance, speed limit, and approaching traffic 2. Destination Lighting for Rural Intersections a. ADT is 1,750 for entering vehicles and intersection is channelized, "T", or a change in direction of the major route b. Night-to-day accident ratio 1.0 or greater with a minimum of 2 nighttime accidents in 5-year period c. Value of "c" exceeds 1,000 points in formula considering sight distance, speed limit, and approaching traffic 3. Complete Interchange – same as AASHTO
Kansas	1. Freeway Interchange a. Total sum of ADT ramp volume for all four ramps exceeds 5,000 for urban, 3,000 for suburban, and 1,000 for rural areas 2. Continuous Freeway a. Closely spaced interchange areas b. Night accidents or unusual geometrics 3. Rural Intersections a. History of nighttime accidents that may be corrected by lighting b. If signal or roundabout is recommended c. Geometrics reduce driver expectation d. Heavy traffic volumes on side streets

	e. Heavy traffic volumes on main street
Maryland	ANSI "Roadway Lighting" RP-8-00
Massachusetts	No
Michigan	No
Minnesota	1. Continuous Freeway a. In and near cities where the ADT is 40,000 or more b. 3 or more interchanges with average spacing 1.5 miles or less c. For a length of 2 miles or more, the freeway passes through development and local traffic has street lighting visible from freeway with streets at spacing of 0.5 mile or less and cross section reduced in width d. Night-to-day crash rate is at least 2 or higher than state average 2. Complete Interchange a. If mainline has continuous lighting 3. Partial Interchange a. Total sum of ADT ramp volume for all four ramps exceeds 5,000 for urban, 5,000 for suburban, and 2,500 for rural areas b. Freeway mainline exceeds ADT of 25,000 for urban, 20,000 for suburban, and 10,000 for rural areas c. Night-to-day crash rate is at least 1.25 or higher than state average 4. At-Grade Intersection a. Traffic signal warrant volume satisfied for any single hour during non-daylight hours b. 3 or more crashes per year during non-daylight hours c. Lighted intersecting roadway d. Adjacent ambient light affects drivers' vision e. Intersection is channelized and speed exceeds 40 mph f. School crossing with 100 or more pedestrians crossing in single hour during non-daylight hours g. Intersection is signalized h. Intersection has flashing beacon
Mississippi	Uses NCHRP Report 152 "Warrants for Highway Lighting" for special areas such as intersections on non-controlled access highways.
Missouri	1. Interchanges - with lighting along major road if one of the following is met: a. ADT on major road exceeds 25,000 for urban; 20,000 for suburban; 10,000 for rural and the crossroad ADT exceeds 1,500 b. Night-to-day crash rate is at least 1.25

	c. Ramp ADT entering and leaving exceeds 5,000 for urban; 3,000 for suburban; and 1,000 for rural and the crossroad ADT exceeds 1,500 2. Intersections (including ramp terminals at crossroad) a. Intersection is signalized b. Divisional islands are used c. ADT on the crossroad exceeds 15,000 for urban conditions d. Lighting provided along freeway e. Night-to-day crash rate exceeds 1.25 f. Poor sight distance exists 3. Continuous Freeway Lighting a. Freeway passes through suburban or urban area for two or more miles and either: • Local traffic operates on a street grid having street lights with parts visible from freeway • Freeway passes through development with some parts lighted • Cross streets occur with an average spacing of ½ mile or less with some ramps lighted • Freeway cross section elements are below desirable standards b. 3 or more interchanges with spacing of 1.5 miles or less with adjacent urban areas c. In or near cities with ADT of 30,000 or more
Montana	Roads with raised median
Nevada	No
New Hampshire	No
New Jersey	Intersections a. Signalized b. Non-signalized that meet one of the following: • 4-lane highway • Nighttime volume – right turn movement greater than 75 VPH, left turn movement greater than 25 VPH, and through movement for intersecting highway greater than 50 VPH in either leg
New York	1. Continuous Lighting on Controlled-Access Highway a. Night-to-day crash rate ratio is at least 3.0 and total accident rate is at least 2 times greater than state average provided 9 or more nighttime accidents per mile per year have occurred over a 3-year period b. 2 or more lighted interchanges with average spacing of ½ mile or less c. ADT is 75,000 or more

	2. Interchanges a. Night-to-day crash rate ratio is at least 2.5 provided 6 or more nighttime accidents per year have occurred over a 3-year period b. Roadway approaches to interchanges and ramps 3. Intersections or Section of Roadway without Access Control a. Night-to-day crash rate ratio is at least 3.0 and total accident rate is at least 2 times greater than state average provided 6 or more nighttime accidents per mile per year or 1 nighttime accident per spot (intersection) have occurred over a 3-year period b. In four nighttime hours, pedestrian volume is 400 per intersection with 600 vehicles entering from all approaches; however, if 85^{th} percentile speed of traffic exceeds 40 mph or lies within a city with population under 10,000 then reduce to 70 percent of requirement
North Carolina	Partial Lighting a. All single-point diamond interchanges
North Dakota	1. Freeway - use AASHTO and a. Freeway sections between completely lighted interchanges that are located within 1 ½ mile or less b. Local government finds sufficient benefit to pay 50% of the installation cost 2. Interchanges a. Ramp ADT entering and leaving exceeds 10,000 for urban; 8,000 for suburban; and 5,000 for rural areas b. ADT on crossroad exceeds 10,000 for urban; 8,000 for suburban; and 5,000 for rural areas c. Lighted commercial or industrial development in vicinity of interchange or where the crossroad approach legs are lighted for ½ mile or more on each side of interchange d. Night-to-day crash rate ratio is at least 1.5 or higher than state average 3. Partial Interchange a. Ramp ADT entering and leaving exceeds 5,000 for urban; 3,000 for suburban; and 1,000 for rural areas b. Freeway mainline exceeds ADT of 25,000 for urban; 20,000 for suburban; and 10,000 for rural areas c. Night-to-day crash rate ratio is at least 1.25 or higher than state average d. Local government finds sufficient benefit to pay 50% of the installation cost 4. US and State Roads a. Reconstruction of roadway will remove existing lighting b. Night-to-day crash rate ratio is at least 2.0 or higher c. Local government finds sufficient benefit to pay 50% of the installation cost

	5. Intersections a. Channelized intersections b. 4 nighttime accidents in one year or 6 or more in 2 years c. 6 or more total accidents in 3 years or less and night-to-day crash rate ratio is 1.5 or higher d. Local government finds sufficient benefit to pay 50% of the installation cost
Ohio	No
Oklahoma	Streets and Highways Other than Freeways a. ADT of 6,000 or more for a 2-lane roadway; 12,000 or more for a 4-lane roadway; 10,000 or more for all approaches of an urban intersection; 4,000 or more for a rural intersection mainline b. Night-to-day crash rate ratio is at least 1.5 or higher c. Potential for accidents due to driveways, channelized islands, development, high percentage of trucks, or geometric deficiencies
Oregon	Non-Limited Access-Controlled Highways a. Lineal section • Accident rate higher than statewide average • Nighttime accident rate exceeds overall accident rate by more than 50 percent b. Spot location • Night exposure rate is at least 50 percent greater than the day rate
Pennsylvania	No
Rhode Island	No
South Carolina	No
Tennessee	No
Texas	No
Washington	1. Freeway ramps 2. Intersections with left turn channelization 3. Intesections with traffic signals 4. Railroad crossings with gates or signals 5. Truck weigh stations 6. Midblock pedestrian crossings 7. Long tunnels

8. Full limited access control highways if 2 of following conditions exist:
    a. 3 or more interchanges with average spacing of 1.5 miles or less
    b. Urban area
    c. Number of nighttime accidents equals or exceeds the number of daytime accidents
9. Full limited access control highway ramps if 2 of following conditions exist:
    a. Alignment and grade are complex
    b. Routine queues of five or more vehicles per lane at the ramp terminal due to traffic control features
    c. Number of nighttime accidents equals or exceeds the number of daytime accidents
10. Highways with partial limited access control
11. Intersections without channelization in commercial area when nighttime peak hour level of service is D or lower and number of nighttime accidents equals or exceeds number of daytime accidents
12. Railroad crossing without gates or signals
13. Walkways and bicycle trails if walkway is between two highway facilities

West Virginia — No

Wyoming — Criteria for interchange and intersection lighting based on assigning points for various criteria.

a. Interchange
    - Geometric conditions (ramp type, roadside development, median width, main line curves, grades, ramp stopping sign distance)
    - Traffic volume (major road, cross road, night ramp)
    - Crash experience (number night crashes, ratio night to day)
b. Intersections
    - Roadway system designation
    - Geometric conditions (intersection type, roadside development, major roadway turn lanes, major roadway posted speed, major roadway stopping sight distance)
    - Traffic volume (major road, minor road, night minor road)
    - Crash experience (number night crashes, ratio night to day)

APPENDIX F. ILLUMINANCE CRITERIA

AASHTO'S GUIDELINES FOR "AVERAGE MAINTAINED ILLUMINANCE"

Average Maintained Horizontal Illuminance* for Roadways Other Than Freeways, Walkways and Bicycle Lanes

Roadway and Walkway Classification		Average Illuminance Pavement Classification: R1 Foot-candles	R1 Lux	R2 & R3 Foot-candles	R2 & R3 Lux	R4 Foot-candles	R4 Lux	Uniformity avg/min
	Commercial	0.9	10	1.3	14	1.2	13	
Expressway**[1]	Intermediate	0.7	8	1.1	12	0.9	10	3:1
	Residential	0.6	6	0.8	9	0.7	8	
	Commercial	1.1	12	1.6	17	1.4	15	
Major[1]	Intermediate	0.8	9	1.2	13	1	11	3:1
	Residential	0.6	6	0.8	9	0.7	8	
	Commercial	0.7	8	1.1	12	0.9	10	
Collector[1]	Intermediate	0.6	6	0.8	9	0.7	8	4:1
	Residential	0.4	4	0.6	6	0.5	5	
	Commercial	0.6	6	0.8	9	0.7	8	
Local[1]	Intermediate	0.5	5	0.7	7	0.6	6	6:1
	Residential	0.3	3	0.4	4	0.4	4	
	Commercial	0.4	4	0.6	6	0.5	5	
Alleys	Intermediate	0.3	3	0.4	4	0.4	4	6:1
	Residential	0.2	2	0.3	3	0.3	3	
	Commercial	0.9	10	1.3	14	1.2	13	3:1
Sidewalks	Intermediate	0.6	6	0.8	9	0.7	8	4:1
	Residential	0.3	3	0.4	4	0.4	4	6:1
Pedestrian Ways and Bicycle Lanes[2]		1.4	15	2	22	1.8	19	3:1

* Average illuminance on the travelled way or on the pavement area between curb lines of curbed roadways. See definition of average maintained illuminance on page 6.

** Both mainline and ramps. Expressways with full control of access are covered in the section on Freeways.

[1]This assumes a separate facility. Facilities adjacent to a vehicular roadway should use the illuminance or luminance levels for the roadway.

[2]Adapted from "American National Standard Practice for Roadway Lighting," ANSI/IESNA RP-8, 1983; Illuminating Engineering Society of North America. Used by Permission

ANSI/IESNA'S GUIDELINES FOR "AVERAGE MAINTAINED ILLUMINANCE"

Illuminance Method - Recommended Values (RP-8)

Road and Pedestrian Conflict Area		Pavement Classification			Uniformity Ratio
Road	Pedestrian Conflict Area	R1 lux / fc	R2 & R3 lux / fc	R4 lux / fc	E_{avg} / E_{min}
Freeway Class A		6.0 / 0.6	9.0 / 0.9	8.0 / 0.8	3.0
Freeway Class B		4.0 / 0.4	6.0 / 0.6	5.0 / 0.5	3.0
Expressway	High	10.0 / 1.0	14.0 / 1.4	13.0 / 1.3	3.0
	Medium	8.0 / 0.8	12.0 / 1.2	10.0 / 1.0	3.0
	Low	6.0 / 0.6	9.0 / 0.9	8.0 / 0.8	3.0
Major	High	12.0 / 1.2	17.0 / 1.7	15.0 / 1.5	3.0
	Medium	9.0 / 0.9	13.0 / 1.3	11.0 / 1.1	3.0
	Low	6.0 / 0.6	9.0 / 0.9	8.0 / 0.8	3.0
Collector	High	8.0 / 0.8	12.0 / 1.2	10.0 / 1.0	4.0
	Medium	6.0 / 0.6	9.0 / 0.9	8.0 / 0.8	4.0
	Low	4.0 / 0.4	6.0 / 0.6	5.0 / 0.5	4.0
Local	High	6.0 / 0.6	9.0 / 0.9	8.0 / 0.8	6.0
	Medium	5.0 / 0.5	7.0/ 0.7	6.0 / 0.6	6.0
	Low	3.0 / 0.3	4.0 / 0.4	4.0 / 0.4	6.0

NCHRP'S GUIDELINES FOR "AVERAGE MAINTAINED ILLUMINANCE"

NCHRP Report 152 "Warrants for Highway Lighting"

Recommendations for Average Maintained Horizontal Illumination		
Roadway Class	**Foot-candles**	**Lux**
Freeways, including major interchanges	0.6	6.0
Primary arterials, expressways, major highways	1.0	11.0
Secondary arterials, major collectors, secondary highways	0.6	6.0
Minor collectors, minor commercial roads	0.4	4.0
Local roads, streets, alleys	0.2	2.0

STATES' GUIDELINES FOR "AVERAGE MAINTAINED ILLUMINANCE"

STATE	SUMMARY (other than AASHTO)
Alabama	ANSI/IESNA RP-8
Alaska	None
Arizona	None
Arkansas	None
California	1. Urban areas and expressways a. 1.6 lux (0.15 fc) in area bounded by crosswalks b. 6.5 lux (0.6 fc) at centerline of entering streets 2. Rural areas a. 1.1 lux (0.10 fc) in area bounded by crosswalks b. 3.2 lux (0.3 fc) at centerline of entering streets
Florida	None
Hawaii	None
Idaho	None
Illinois	Yes (same table as AASHTO)
Indiana	1. Interstate / Freeways a. 8 lux (0.74 fc) 2. Expressway a. 12 lux (1.16 fc) 3. Intersection and City Street a. 9 lux (0.84 fc)
Iowa	---
Kansas	None
Maryland	ANSI/IESNA RP-8, Annex D
Massachusetts	None
Michigan	None
Minnesota	Yes (reference to AASHTO)
Mississippi	None
Missouri	1. Freeways, urban arterials, expressways, and ramps a. at least 6.5 lux (0.6 fc) 2. Other roadways not listed in #1 a. 4.3 lux (0.4 fc) 3. Intersections a. 6.5 lux (0.6 fc) 4. Divisional and channelized islands with non-mountable curbs a. 2.2 lux (0.2 fc)
Montana	None
New Hampshire	None
New Jersey	1. Mainline highways and ramps a. 6.4 lux (0.59 fc) to 8.6 lux (0.8 fc) 2. Intersections

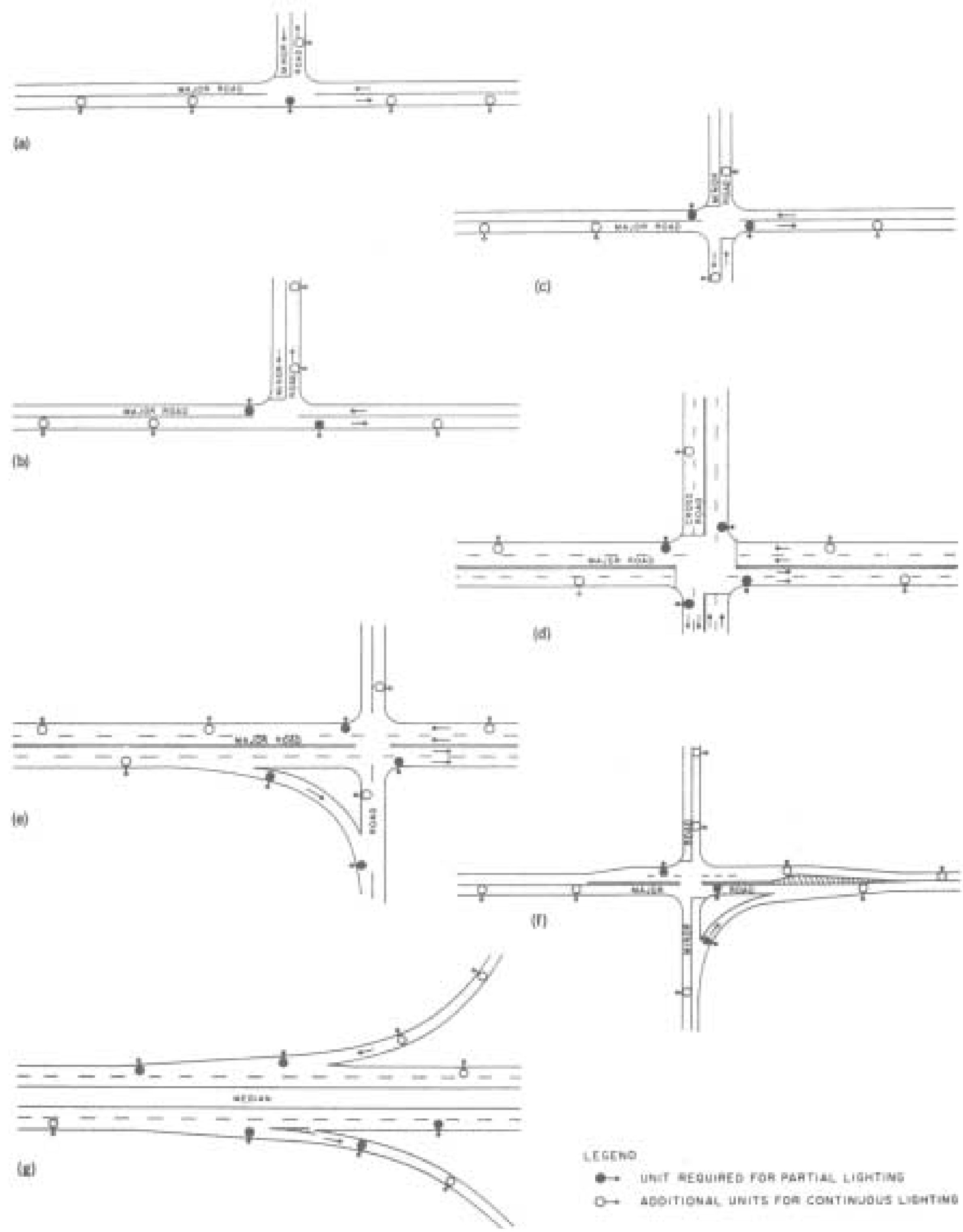
	b. 6.4 lux (0.59 fc) to 8.6 lux (0.8 fc)
New York	ANSI/IESNA RP-8
Nevada	None
North Carolina	None
North Dakota	None
Ohio	None
Oklahoma	Yes (table as given in AASHTO)
Oregon	None
Pennsylvania	None
Rhode Island	None
South Carolina	None
Tennessee	None
Texas	None
Washington	1. Full limited access control highways a. 6.5 lux (0.6 fc) to 9.7 lux (0.9 fc) depending on pedestrian classification 2. Other roadways a. 6.5 lux (0.6 fc) to 17.2 lux (1.6 fc) depending on pedestrian classification
West Virginia	None
Wyoming	None

APPENDIX G. LIGHTING DESIGN EXAMPLES

GUIDELINES FOR DESIGN
(NUMBER AND PLACEMENT OF LUMINARIES)

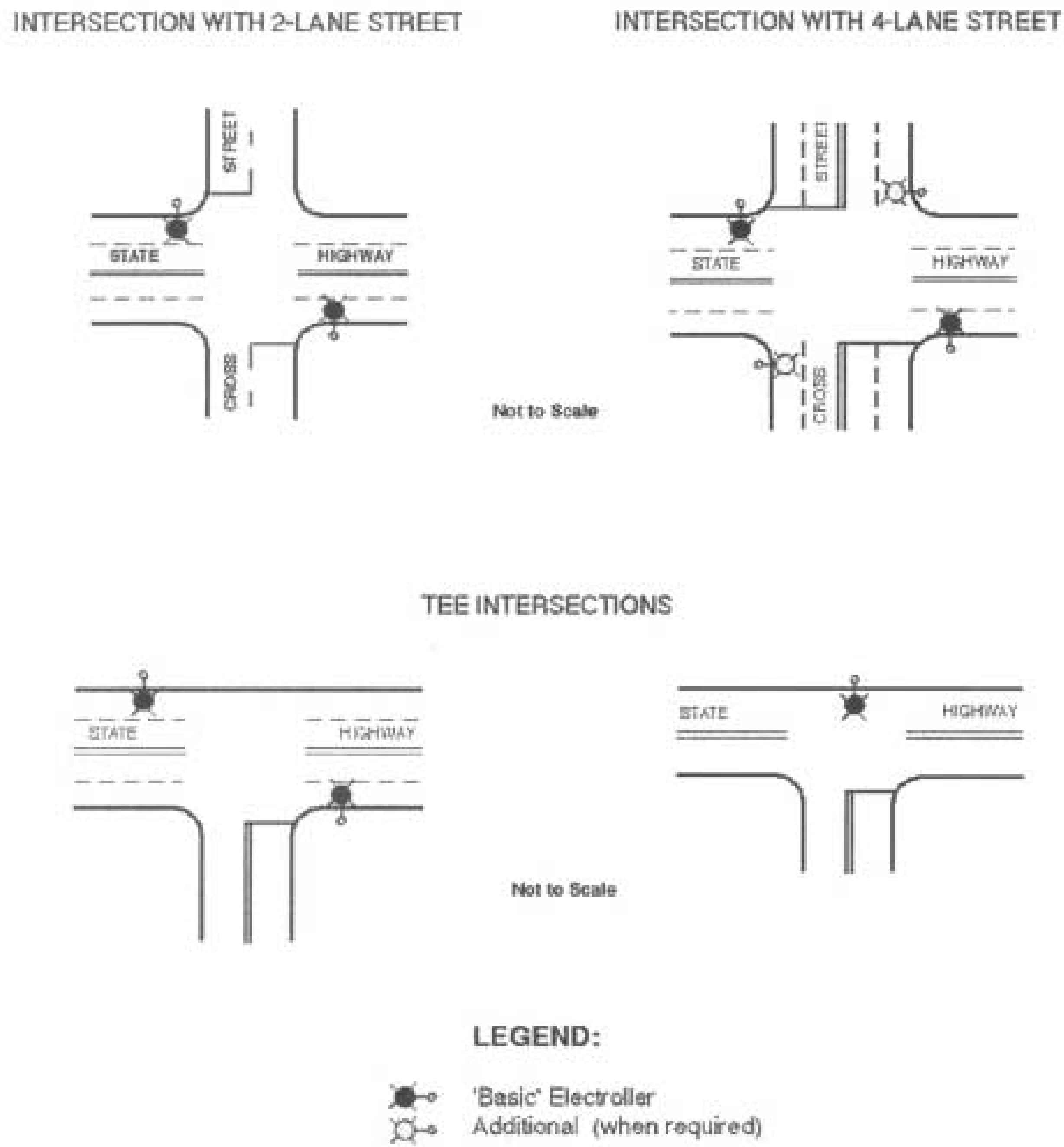
STATE	
Alabama	No
Alaska	No
Arizona	No
Arkansas	No
California	Yes
Florida	Yes
Hawaii	No
Idaho	No
Illinois	Yes
Indiana	Yes
Iowa	No
Kansas	Yes
Maryland	Yes (examples for partial lighting given in ANSI/IESNA RP-8)
Massachusetts	No
Michigan	No
Minnesota	No
Mississippi	No
Missouri	Yes
Montana	No
New Hampshire	No
New Jersey	No
New York	No
Nevada	No
North Carolina	Yes (cut-off optics to prevent "light pollution")
North Dakota	No
Ohio	No
Oklahoma	No
Oregon	Yes
Pennsylvania	No
Rhode Island	No
South Carolina	No
Tennessee	No
Texas	No
Washington	Yes
West Virginia	No
Wyoming	No

(EXAMPLES FOLLOW)

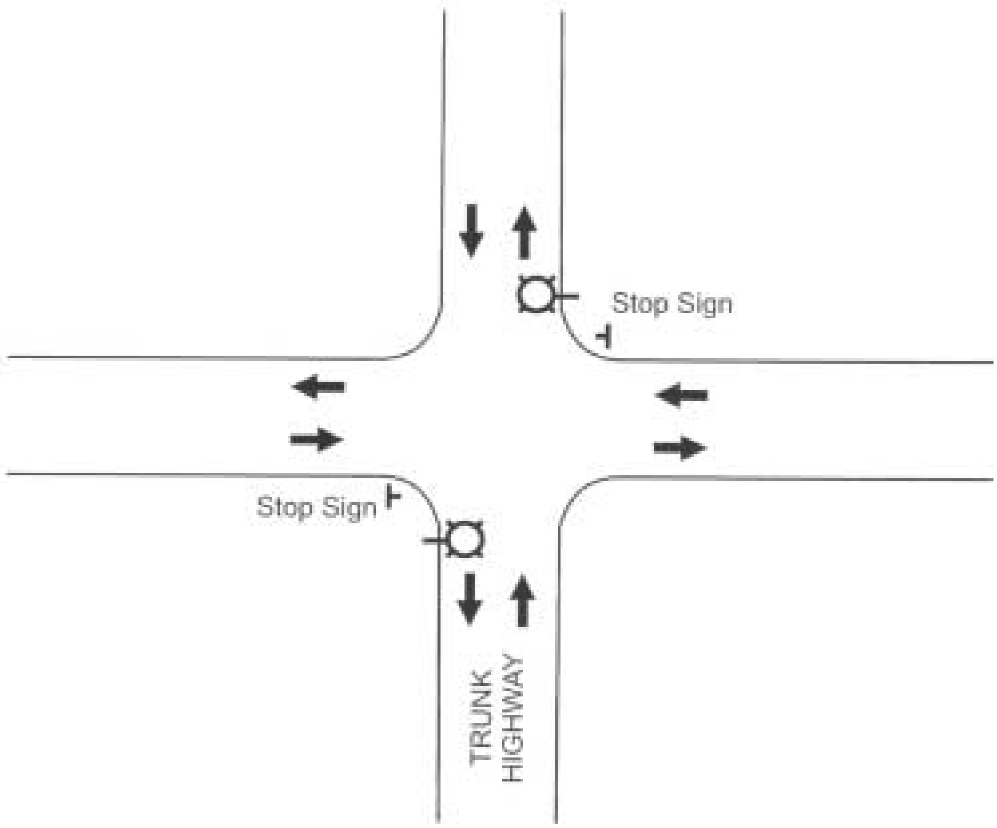


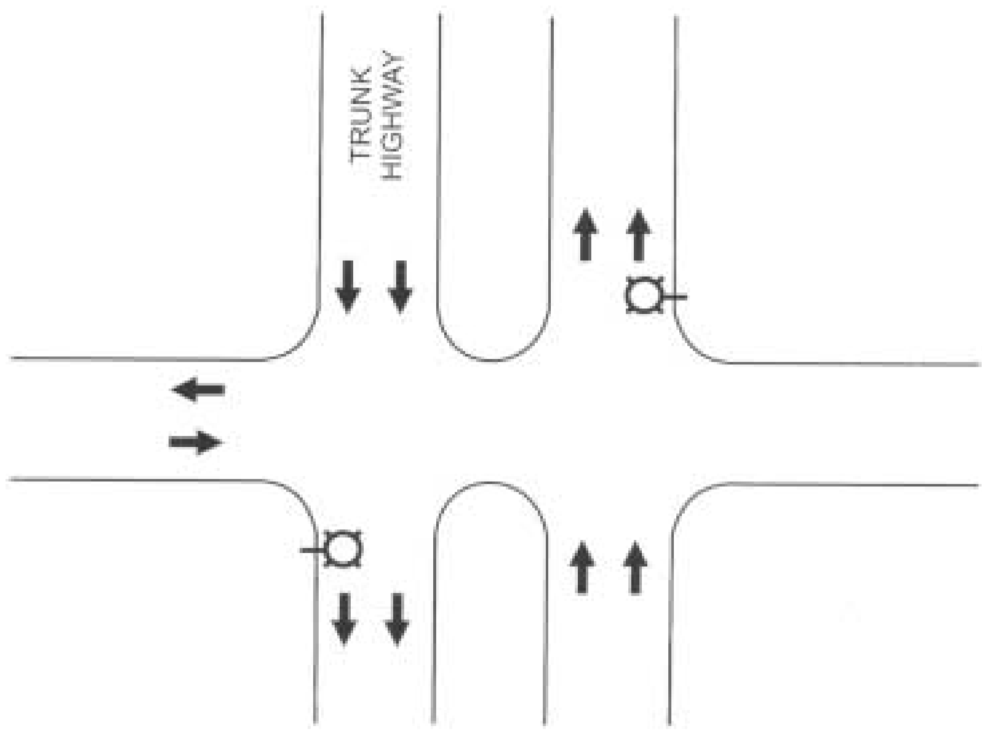
MAJOR ROAD
MINOR ROAD
CROSS ROAD
MEDIAN
(a)
(b)
(c)
(d)
(e)
(f)
(g)
LEGEND
UNIT REQUIRED FOR PARTIAL LIGHTING
ADDITIONAL UNITS FOR CONTINUOUS LIGHTING

California Lighting Design Configurations

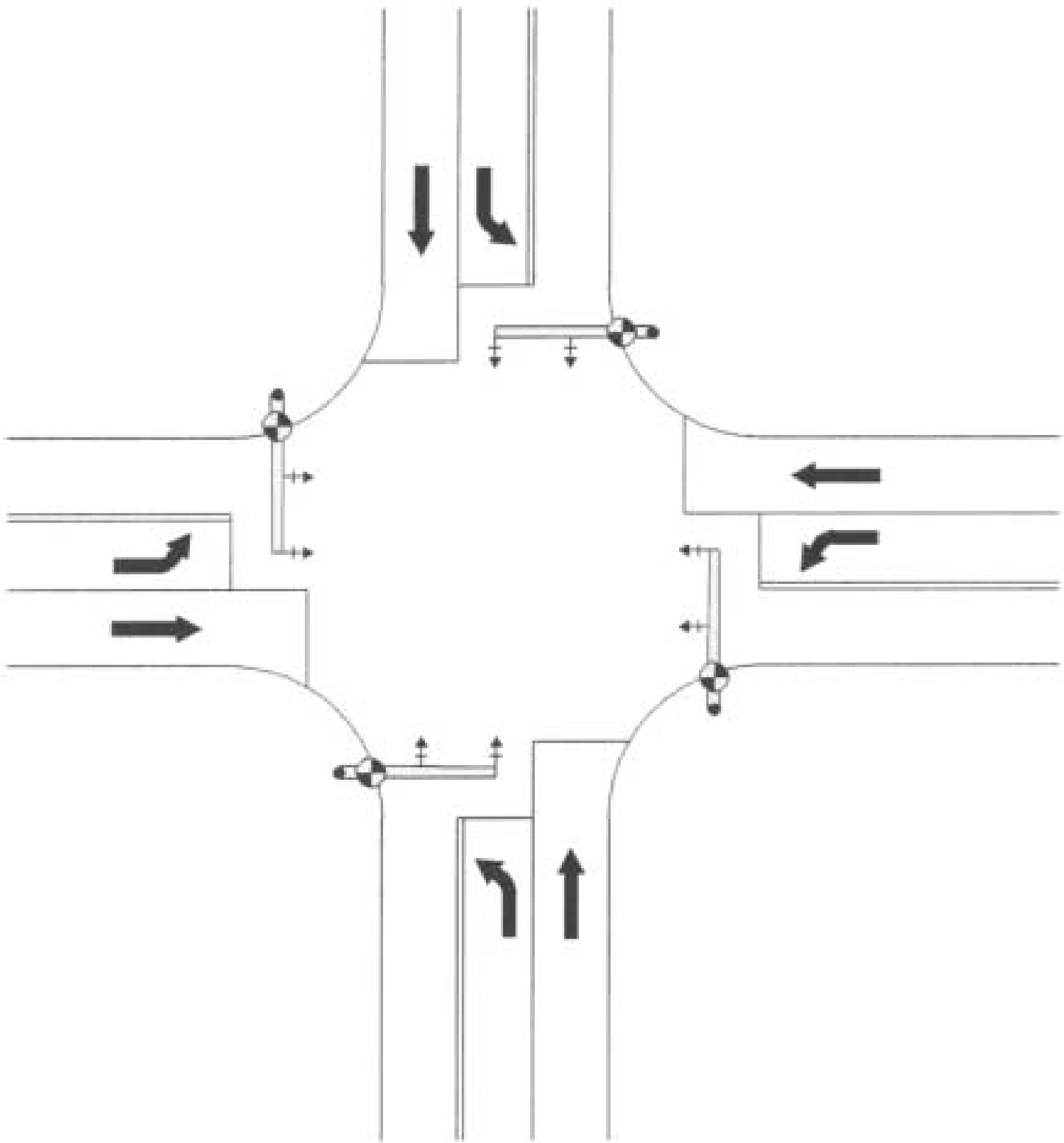


Minnesota Lighting Design Configurations

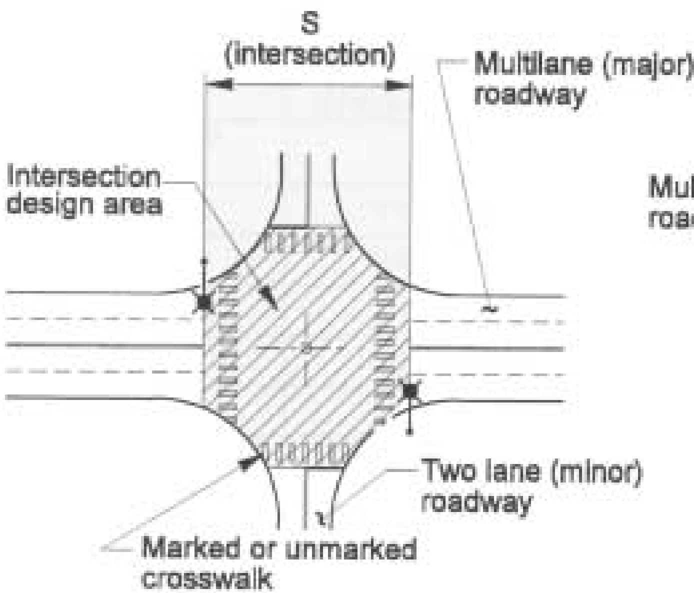




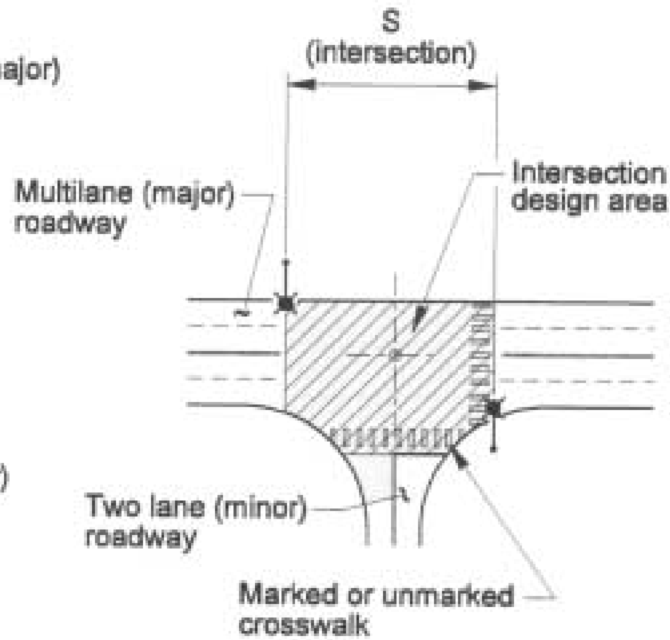
Missouri Lighting Design Configuration



Washington Lighting Design Configurations



Four Way Intersection
(Without left turn channelization)



Tee Intersection Major
(Without left turn channelization)

APPENDIX H. 0.3-MILE SPOTS WITH A CRF OF 2.0 OR MORE (NIGHTTIME CRASHES WITH NO LIGHTING) (2000-2002 DATA)

APPENDIX H. ALL 0.3-MILE SPOTS WITH A CRITICAL NUMBER OF THREE OR MORE CRASHES OCCURRING AT NIGHTTIME WITH A CRITICAL RATE FACTOR OF 2 OR MORE USING CRASH DATA FROM 2000 TO 2002

HD	CO	RT	SU	CRASH	BMP	EMP	ADT	RU	NL	MT	FC	Cact	Crate	CRF
1	18	1483		6	2.815	3.098	357	Rural	2	none	9 local	95.367	20.079	4.750
2	89	973		7	5.900	6.200	615	Rural	2	none	8 minc	64.586	14.129	4.571
3	114	2665		6	4.546	4.777	447	Rural	2	none	9 local	76.166	17.310	4.400
7	76	1986		9	0.337	0.372	1422	Rural	2	none	8 minc	35.914	8.645	4.154
7	120	1967		7	5.187	5.441	1078	Rural	2	none	8 minc	36.846	10.099	3.648
4	14	333		5	12.800	13.100	495	Rural	2	none	8 minc	57.317	16.207	3.537
11	63	830		5	3.908	4.203	495	Rural	2	none	8 minc	57.317	16.207	3.537
1	73	996		4	3.511	3.549	262	Rural	2	none	Mixed	86.631	24.799	3.493
6	96	1054		4	2.026	2.320	265	Rural	2	none	8 minc	85.651	24.603	3.481
3	114	263		7	0.575	0.800	1247	Rural	2	none	8 minc	31.853	9.298	3.426
5	106	53		10	11.421	11.641	2683	Rural	2	none	7 majc	21.149	6.210	3.406
4	14	144		4	10.700	10.998	310	Rural	2	none	8 minc	73.217	22.087	3.315
3	114	101		6	11.641	11.841	941	Rural	2	none	6 ma	36.181	10.927	3.311
6	94	227		5	24.808	25.008	616	Rural	2	none	7 majc	46.058	14.114	3.263
7	105	32		7	5.790	6.041	1429	Rural	2	none	8 minc	27.796	8.621	3.224
1	38	309		5	3.900	4.057	652	Rural	2	none	8 minc	43.515	13.626	3.194
6	59	1829		12	3.595	3.845	5213	Urban	2	none	17 c	12.394	3.988	3.108
6	49	1284		4	5.065	5.365	396	Rural	2	none	8 minc	57.317	18.741	3.058
6	49	356		4	8.128	8.258	407	Rural	2	none	8 minc	55.768	18.405	3.030
9	35	11		7	0.000	0.300	1671	Rural	2	none	6 ma	23.770	7.921	3.001
7	105	1973		6	0.456	0.610	1220	Rural	2	none	8 minc	27.907	9.413	2.965
4	50	1140		4	5.744	5.944	440	Rural	2	none	8 minc	51.585	17.489	2.950
6	96	609		3	1.110	1.123	181	Rural	2	none	8 minc	94.050	32.250	2.916
1	73	68		11	0.991	1.108	9510	Rural	4	unprot	2 pa oth	6.563	2.251	2.916
7	76	421		12	7.683	7.983	5138	Rural	2	none	6 ma	13.253	4.593	2.886
1	79	68		9	9.232	9.504	6760	Rural	4	Mixed	2 pa oth	7.555	2.639	2.863
6	8	14		8	0.983	1.186	2470	Rural	2	none	7 majc	18.378	6.470	2.841
6	41	489		4	3.807	3.907	530	Rural	2	none	8 minc	42.825	15.515	2.760
1	73	1954		12	2.891	3.029	6520	Urban	2	none	16 ma	9.909	3.616	2.740
7	120	1681		6	11.828	12.100	1495	Rural	2	none	7 majc	22.773	8.411	2.707
5	37	1005		5	6.683	6.790	1159	Urban	2	none	17 c	23.228	8.635	2.690
5	108	44		8	0.352	0.552	2850	Rural	2	none	7 majc	15.928	6.029	2.642
6	41	330		4	3.684	3.953	602	Rural	2	none	8 minc	37.703	14.318	2.633
7	40	1355		4	12.213	12.313	604	Rural	2	none	8 minc	37.579	14.289	2.630
7	105	25		6	10.838	11.047	1640	Rural	2	none	7 majc	20.760	8.001	2.595
5	15	44		7	8.500	8.800	2320	Rural	2	none	7 majc	17.121	6.677	2.564
12	98	194		5	13.863	13.990	1122	Rural	2	none	8 minc	25.287	9.871	2.562
5	15	1526		5	9.600	9.900	1139	Rural	2	none	8 minc	24.909	9.786	2.545
7	25	974		4	3.154	3.335	664	Rural	2	none	8 minc	34.183	13.474	2.537
4	82	261		4	0.809	1.028	674	Rural	2	none	8 minc	33.676	13.350	2.522
9	10	1012		7	2.347	2.580	2791	Urban	2	none	17 c	13.504	5.365	2.517
3	107	1171		4	3.705	3.990	699	Rural	2	none	8 minc	32.471	13.055	2.487
5	37	1665		4	3.993	4.272	701	Rural	2	none	8 minc	32.379	13.032	2.484
12	58	825		3	3.710	3.710	311	Rural	2	none	8 minc	54.737	22.039	2.484
8	1	206		7	2.200	2.500	2504	Rural	2	none	7 majc	15.863	6.426	2.469
8	116	92		6	12.000	12.300	1858	Rural	2	none	7 majc	18.324	7.488	2.447
7	25	3369		3	1.000	1.237	332	Rural	2	none	8 minc	51.274	21.083	2.432
5	37	1665		8	0.070	0.320	3370	Rural	2	none	Mixed	13.470	5.562	2.422
5	56	60		6	12.895	13.095	1851	Urban	4	unprot	14 pa non	17.453	7.208	2.421
11	63	1193		4	1.819	2.000	749	Rural	2	none	7 majc	30.304	12.518	2.421
8	29	449		3	2.019	2.129	340	Rural	2	none	8 minc	50.068	20.747	2.413
1	42	534		3	3.447	3.561	340	Rural	2	none	8 minc	50.068	20.747	2.413
4	82	376		4	1.789	2.029	757	Rural	2	none	7 majc	29.983	12.438	2.411
12	36	979		7	13.723	13.928	2625	Rural	2	none	7 majc	15.132	6.277	2.411
3	114	185		7	11.007	11.300	2660	Rural	2	none	7 majc	14.933	6.236	2.395
6	49	982		3	1.945	1.982	351	Rural	2	none	9 local	48.499	20.308	2.388
7	105	32		3	24.349	24.544	351	Rural	2	none	7 majc	48.499	20.308	2.388
12	67	588		4	6.016	6.263	783	Rural	2	none	8 minc	28.988	12.187	2.379
4	14	2779		3	2.810	2.943	356	Rural	2	none	9 local	47.818	20.116	2.377
7	105	620		3	5.138	5.338	364	Rural	2	none	8 minc	46.767	19.820	2.360
4	78	289		4	2.841	2.847	800	Rural	2	none	7 majc	28.372	12.030	2.358
5	37	420		10	0.881	1.181	5319	Rural	2	none	8 minc	10.668	4.524	2.358

APPENDIX H. ALL 0.3-MILE SPOTS WITH A CRITICAL NUMBER OF THREE OR MORE CRASHES OCCURRING AT NIGHTTIME WITH A CRITICAL RATE FACTOR OF 2 OR MORE USING CRASH DATA FROM 2000 TO 2002 (continued)

HD	CO	RT	SU	CRASH	BMP	EMP	ADT	RU	NL	MT	FC	Cact	Crate	CRF
1	73	1954		6	2.066	2.331	2011	Rural	2	none	8 minc	16.930	7.185	2.356
2	117	56		5	8.300	8.594	1360	Rural	2	none	7 majc	20.862	8.860	2.355
9	103	377		6	4.958	5.258	2019	Rural	2	none	7 majc	16.863	7.170	2.352
11	61	1304		7	1.936	2.200	2789	Rural	2	none	8 minc	14.242	6.093	2.338
4	78	84		5	7.210	7.400	1388	Rural	2	none	7 majc	20.441	8.761	2.333
3	71	73		3	2.064	2.115	377	Rural	2	none	8 minc	45.154	19.362	2.332
6	59	2044		3	2.170	2.290	438	Urban	2	none	17 c	36.878	15.826	2.330
7	120	1965		3	5.251	5.504	379	Rural	2	none	8 minc	44.916	19.294	2.328
4	90	605		4	0.571	0.700	832	Rural	2	none	8 minc	27.281	11.752	2.321
8	116	167		3	16.770	17.000	385	Rural	2	none	8 minc	44.216	19.094	2.316
5	37	2820		3	1.361	1.530	387	Rural	2	none	8 minc	43.987	19.028	2.312
2	51	1299		3	6.800	7.100	392	Rural	2	none	8 minc	43.426	18.867	2.302
6	12	10		6	12.361	12.604	2117	Rural	2	none	7 majc	16.082	6.997	2.299
1	18	783		3	16.257	16.257	394	Rural	2	none	9 local	43.206	18.804	2.298
7	57	1268		3	5.974	6.274	394	Rural	2	none	8 minc	43.206	18.804	2.298
4	62	224		3	0.689	0.827	404	Rural	2	none	8 minc	42.136	18.495	2.278
6	39	455		4	5.552	5.611	872	Rural	2	none	8 minc	26.029	11.428	2.278
5	15	480		6	3.900	4.100	2164	Rural	2	none	7 majc	15.733	6.918	2.274
3	31	259		8	12.096	12.196	3810	Rural	2	none	6 ma	11.915	5.252	2.268
11	48	2007		4	0.600	0.900	885	Rural	2	none	8 minc	25.647	11.329	2.264
7	120	1681		5	11.426	11.682	1495	Rural	2	none	7 majc	18.978	8.411	2.256
10	77	867		3	5.530	5.810	418	Rural	2	none	8 minc	40.725	18.086	2.252
2	113	130		6	14.230	14.500	2211	Rural	2	none	7 majc	15.399	6.843	2.250
2	92	62		6	12.980	13.009	2220	Rural	2	none	7 majc	15.336	6.828	2.246
3	2	585		3	3.000	3.178	429	Rural	2	none	8 minc	39.681	17.781	2.232
4	82	1816		4	3.718	4.000	919	Rural	2	none	8 minc	24.698	11.080	2.229
7	34	1927		6	6.267	6.367	2663	Urban	2	none	16 ma	12.131	5.494	2.208
2	117	132		5	12.100	12.309	1585	Rural	2	none	7 majc	17.900	8.149	2.197
2	51	41		6	3.160	3.172	2335	Rural	2	none	7 majc	14.581	6.656	2.191
7	9	1970		3	0.300	0.589	457	Rural	2	none	9 local	37.250	17.064	2.183
8	100	1674		5	0.700	1.000	1609	Rural	2	none	8 minc	17.633	8.083	2.181
8	100	1674		5	1.600	1.900	1609	Rural	2	none	8 minc	17.633	8.083	2.181
12	98	119		9	27.105	27.314	11276	Rural	4	unprot	2 pa oth	4.529	2.087	2.170
11	61	3436		3	0.700	0.960	469	Rural	2	none	8 minc	36.297	16.780	2.163
5	106	395		5	10.255	10.484	1649	Rural	2	none	7 majc	17.205	7.977	2.157
4	43	2766		3	0.200	0.500	477	Rural	2	none	9 local	35.688	16.597	2.150
9	68	377		3	4.055	4.300	485	Rural	2	none	7 majc	35.099	16.421	2.137
2	92	505		3	2.980	3.200	486	Rural	2	none	8 minc	35.027	16.399	2.136
3	5	87		4	4.900	5.115	1020	Rural	2	none	8 minc	22.252	10.426	2.134
2	30	2127		3	0.500	0.700	488	Rural	2	none	9 local	34.883	16.356	2.133
3	114	526		5	5.883	6.115	1696	Rural	2	none	8 minc	16.729	7.858	2.129
3	71	1038		3	3.998	4.099	496	Rural	2	none	8 minc	34.321	16.186	2.120
5	106	148		4	9.200	9.254	1037	Rural	2	none	8 minc	21.888	10.327	2.119
9	45	1458		6	0.850	1.150	2500	Rural	2	none	8 minc	13.618	6.431	2.118
8	112	42		4	8.900	9.100	1060	Rural	2	none	7 majc	21.413	10.197	2.100
3	85	1243		4	7.335	7.516	1066	Rural	2	none	8 minc	21.292	10.164	2.095
7	84	1988		3	2.700	3.000	516	Rural	2	none	9 local	32.990	15.782	2.090
2	54	1687		3	4.292	4.526	519	Rural	2	none	8 minc	32.800	15.723	2.086
9	81	435		3	3.200	3.400	519	Rural	2	none	8 minc	32.800	15.723	2.086
1	4	51		6	1.700	1.900	2578	Rural	2	none	2 pa oth	13.206	6.334	2.085
3	107	383		3	3.947	4.189	520	Rural	2	none	7 majc	32.737	15.704	2.085
6	21	2350		4	0.952	1.187	1080	Rural	2	none	9 local	21.016	10.088	2.083
7	87	713		4	13.738	13.776	1080	Rural	2	none	7 majc	21.016	10.088	2.083
7	87	646		4	4.500	4.600	1090	Rural	2	none	8 minc	20.823	10.035	2.075
9	91	1455		4	1.200	1.474	1090	Rural	2	none	8 minc	20.823	10.035	2.075
7	57	1268		3	12.062	12.070	527	Rural	2	none	8 minc	32.302	15.571	2.074
6	59	1486		4	2.685	2.943	1266	Urban	2	none	17 c	17.012	8.206	2.073
6	19	824		4	0.769	0.958	1095	Rural	2	none	8 minc	20.728	10.009	2.071
6	59	536		8	1.881	2.165	5222	Urban	2	none	16 ma	8.248	3.985	2.070
12	36	979		6	14.023	14.307	2625	Rural	2	none	7 majc	12.970	6.277	2.066
4	78	1157		3	0.200	0.500	533	Rural	2	none	8 minc	31.938	15.459	2.066
2	89	181		5	5.856	6.121	1810	Rural	2	none	7 majc	15.675	7.591	2.065
7	34	2335		3	0.693	0.991	620	Urban	2	none	19 local	26.052	12.628	2.063

APPENDIX H. ALL 0.3-MILE SPOTS WITH A CRITICAL NUMBER OF THREE OR MORE CRASHES OCCURRING AT NIGHTTIME WITH A CRITICAL RATE FACTOR OF 2 OR MORE USING CRASH DATA FROM 2000 TO 2002 (continued)

HD	CO	RT	SU	CRASH	BMP	EMP	ADT	RU	NL	MT	FC	Cact	Crate	CRF
5	56	9065		47	135.717	136.015	131907	Urban	6	pos bar	11 pa int	1.763	0.671	2.626
5	56	61		33	3.417	3.717	28300	Urban	4	none	14 pa non	6.278	2.396	2.620
5	56	61		9	12.573	12.852	4217	Urban	2	none	16 ma	11.491	4.393	2.616
5	56	155		36	11.295	11.595	32340	Urban	4	unprot	14 pa non	5.993	2.308	2.597
5	93	53		6	2.500	2.624	1657	Rural	2	none	6 ma	20.547	7.957	2.582
5	15	44		7	8.500	8.800	2320	Rural	2	none	7 majc	17.121	6.677	2.564
5	15	1526		5	9.600	9.900	1139	Rural	2	none	8 minc	24.909	9.786	2.545
5	37	1665		4	3.993	4.272	701	Rural	2	none	8 minc	32.379	13.032	2.484
5	37	1665		8	0.000	0.300	3370	Rural	2	none	Mixed	13.470	5.562	2.422
5	56	60		6	13.357	13.657	1851	Urban	4	unprot	Mixed	17.453	7.208	2.421
5	15	9065		23	116.991	117.200	72153	Rural	6	unprot	1 pa int	1.452	0.600	2.420
5	56	1631		20	1.078	1.373	15392	Urban	6	curbed	16 ma	6.996	2.898	2.414
5	56	9065		43	132.955	133.106	131907	Urban	6	pos bar	11 pa int	1.613	0.671	2.402
5	37	420		10	0.881	1.181	5319	Rural	2	none	8 minc	10.668	4.524	2.358
5	106	395		5	8.270	8.570	1434	Rural	2	none	7 majc	19.785	8.605	2.299
5	56	31	E	26	13.303	13.599	24300	Urban	4	none	14 pa non	5.761	2.506	2.299
5	56	31	E	11	17.471	17.726	6450	Urban	4	none	14 pa non	9.182	4.017	2.286
5	15	480		6	3.900	4.100	2164	Rural	2	none	7 majc	15.733	6.918	2.274
5	56	60		4	13.709	14.000	1949	Rural	4	unprot	6 ma	11.646	5.141	2.265
5	56	31	W	7	19.770	20.070	3443	Urban	2	none	14 pa non	10.947	4.837	2.263
5	56	1747		40	4.306	4.601	45031	Urban	6	unprot	14 pa non	4.783	2.115	2.261
5	56	61		9	11.545	11.783	5518	Urban	2	none	16 ma	8.782	3.888	2.259
5	37	127		12	3.710	4.009	17730	Rural	4	Mixed	2 pa oth	3.841	1.729	2.221
5	56	60		19	2.677	2.963	16400	Urban	4	none	14 pa non	6.238	2.837	2.198
5	56	31	E	22	14.977	15.275	24250	Urban	2	none	14 pa non	4.885	2.223	2.197
5	56	3064		6	0.000	0.228	2770	Urban	2	none	16 ma	11.662	5.386	2.165
5	106	395		5	8.706	8.972	1649	Rural	2	none	7 majc	17.205	7.977	2.157
5	106	395		5	10.255	10.484	1649	Rural	2	none	7 majc	17.205	7.977	2.157
5	106	148		4	9.200	9.254	1037	Rural	2	none	8 minc	21.888	10.327	2.119
5	15	1526		16	11.200	11.459	13468	Urban	4	curbed	16 ma	6.396	3.034	2.108
5	56	60		31	7.735	8.010	35906	Urban	4	none	14 pa non	4.648	2.243	2.072
5	56	1447		23	6.400	6.700	23683	Urban	4	unprot	16 ma	5.229	2.525	2.071
5	56	1747		23	0.000	0.300	23770	Urban	4	curbed	14 pa non	5.210	2.523	2.065
5	56	1865		13	1.264	1.564	12000	Urban	2	none	16 ma	5.833	2.832	2.060
5	56	1020		9	12.097	12.295	5507	Urban	4	none	14 pa non	8.799	4.293	2.050
5	37	9064		12	52.918	53.156	34200	Rural	4	unprot	1 pa int	1.598	0.780	2.047
5	56	9064		32	4.800	5.090	111602	Urban	4	pos bar	11 pa int	1.419	0.701	2.025
5	56	1020		12	8.874	9.170	9150	Urban	4	none	16 ma	7.061	3.495	2.020
5	56	660		3	0.100	0.300	567	Rural	2	none	8 minc	30.023	14.866	2.020
5	106	395		3	6.264	6.513	573	Rural	2	none	8 minc	29.709	14.768	2.012
5	56	9065		36	131.943	132.200	131907	Urban	6	pos bar	11 pa int	1.350	0.671	2.011
5	56	61		8	12.000	12.234	5518	Urban	2	none	16 ma	7.806	3.888	2.008
6	19	27		28	21.436	21.691	5376	Urban	2	none	14 pa non	28.042	3.933	7.129
6	59	17		17	22.283	22.557	3185	Urban	2	none	14 pa non	28.738	5.025	5.720
6	41	22		12	10.828	11.087	2942	Rural	4	Mixed	7 majc	23.145	4.061	5.700
6	59	25		17	4.855	5.096	8153	Rural	4	none	Mixed	11.832	2.415	4.899
6	19	8		27	0.306	0.604	9710	Urban	2	none	14 pa non	14.971	3.071	4.875
6	59	17		24	22.968	23.235	8217	Urban	2	none	14 pa non	15.726	3.283	4.790
6	19	27		27	21.789	22.079	10500	Urban	2	none	14 pa non	13.845	2.979	4.647
6	19	27		15	22.117	22.296	3287	Urban	4	Mixed	14 pa non	24.570	5.415	4.538
6	59	17		21	23.642	23.898	8217	Urban	2	none	14 pa non	13.760	3.283	4.191
6	19	1120		16	0.000	0.271	6983	Urban	2	none	14 pa non	12.337	3.512	3.512
6	96	1054		4	2.026	2.320	265	Rural	2	none	8 minc	85.651	24.603	3.481
6	59	8		35	6.669	6.954	13800	Urban	3	none	14 pa non	13.655	4.185	3.263
6	94	227		5	24.808	25.008	616	Rural	2	none	7 majc	46.058	14.114	3.263
6	59	1829		12	3.595	3.845	5213	Urban	2	none	17 c	12.394	3.988	3.108
6	49	1284		4	5.065	5.365	396	Rural	2	none	8 minc	57.317	18.741	3.058
6	49	356		4	8.128	8.258	407	Rural	2	none	8 minc	55.768	18.405	3.030
6	19	27		25	21.134	21.388	16123	Urban	4	none	14 pa non	8.349	2.854	2.926
6	96	609		3	1.110	1.123	181	Rural	2	none	8 minc	94.050	32.250	2.916
6	8	14		8	0.983	1.186	2470	Rural	2	none	7 majc	18.378	6.470	2.841
6	19	27		10	0.000	0.262	8380	Rural	4	none	6 ma	6.771	2.385	2.840
6	59	8		16	6.981	7.236	10300	Urban	2	none	14 pa non	8.364	3.001	2.787

APPENDIX H. ALL 0.3-MILE SPOTS WITH A CRITICAL NUMBER OF THREE OR MORE CRASHES OCCURRING AT NIGHTTIME WITH A CRITICAL RATE FACTOR OF 2 OR MORE USING CRASH DATA FROM 2000 TO 2002 (continued)

HD	CO	RT	SU	CRASH	BMP	EMP	ADT	RU	NL	MT	FC	Cact	Crate	CRF
6	8	1925		3	6.287	6.488	538	Rural	2	none	9 local	31.641	15.368	2.059
2	117	138		3	6.401	6.700	539	Rural	2	none	8 minc	31.583	15.350	2.058
1	73	450		5	4.273	4.525	1837	Rural	2	none	7 majc	15.445	7.532	2.050
1	73	450		5	6.412	6.512	1837	Rural	2	none	7 majc	15.445	7.532	2.050
4	90	46		3	6.551	6.600	547	Rural	2	none	8 minc	31.121	15.207	2.046
1	73	1322		4	5.096	5.396	1126	Rural	2	none	8 minc	20.158	9.851	2.046
6	12	19		4	13.096	13.200	1136	Rural	2	none	7 majc	19.980	9.801	2.039
2	30	60		7	4.223	4.500	3640	Rural	2	none	6 ma	10.912	5.365	2.034
9	103	2342		4	1.224	1.372	1328	Urban	2	none	17 c	16.217	7.985	2.031
9	81	62		4	0.019	0.200	1160	Rural	2	none	7 majc	19.567	9.685	2.020
5	56	660		3	0.100	0.300	567	Rural	2	none	8 minc	30.023	14.866	2.020
6	21	1226		3	2.045	2.274	568	Rural	2	none	8 minc	29.970	14.850	2.018
5	56	60		5	13.357	13.657	1851	Urban	4	unprot	Mixed	14.544	7.208	2.018
12	67	805		6	5.200	5.300	2753	Rural	2	none	7 majc	12.367	6.132	2.017
5	106	395		3	6.264	6.513	573	Rural	2	none	8 minc	29.709	14.768	2.012
3	114	2632		3	4.310	4.457	573	Rural	2	none	9 local	29.709	14.768	2.012
11	61	1304		6	0.783	1.008	2789	Rural	2	none	8 minc	12.207	6.093	2.004
4	82	228		4	15.733	15.913	1183	Rural	2	none	7 majc	19.186	9.578	2.003

APPENDIX I. NIGHTTIME TRAFFIC VOLUMES PERCENTAGES IN KENTUCKY BY HOUR AND MONTH

APPENDIX I-1. NIGHTTIME TRAFFIC VOLUMES PERCENTAGES IN KENTUCKY FOR RURAL INTERSTATES/PARKWAYS BY HOUR AND MONTH

	January	February	March	April	May	June	July	August	September	October	November	December
MIDNIGHT	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
1:00 AM	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
2:00 AM	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
3:00 AM	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
4:00 AM	1.38	1.38	1.38	1.38	1.38	0	1.38	1.38	1.38	1.38	1.38	1.38
5:00 AM	2.10	2.10	2.10	0	0	0	0	0	0	2.10	2.10	2.10
6:00 AM	3.96	3.96	0	0	0	0	0	0	0	0	0	3.96
7:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
8:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
9:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
10:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
11:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
NOON	0	0	0	0	0	0	0	0	0	0	0	0
1:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
2:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
3:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
4:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
5:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
6:00 PM	0	0	0	0	0	0	0	0	0	0	0	5.36
7:00 PM	4.13	4.13	0	0	0	0	0	0	0	4.13	4.13	4.13
8:00 PM	3.32	3.32	3.32	3.32	0	0	0	0	3.32	3.32	3.32	3.32
9:00 PM	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91
10:00 PM	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38
11:00 PM	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Monthly Totals	*27.26*	*27.26*	*19.17*	*17.07*	*13.75*	*12.37*	*13.75*	*13.75*	*17.07*	*23.30*	*23.30*	*32.62*

Total **20.06**

APPENDIX I-2. NIGHTTIME TRAFFIC VOLUMES PERCENTAGES IN KENTUCKY FOR RURAL OTHER BY HOUR AND MONTH

	January	February	March	April	May	June	July	August	September	October	November	December
MIDNIGHT	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
1:00 AM	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
2:00 AM	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
3:00 AM	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
4:00 AM	0.66	0.66	0.66	0.66	0.66	0	0.66	0.66	0.66	0.66	0.66	0.66
5:00 AM	1.97	1.97	1.97	0	0	0	0	0	0	1.97	1.97	1.97
6:00 AM	4.51	4.51	0	0	0	0	0	0	0	0	0	4.51
7:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
8:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
9:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
10:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
11:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
NOON	0	0	0	0	0	0	0	0	0	0	0	0
1:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
2:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
3:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
4:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
5:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
6:00 PM	0	0	0	0	0	0	0	0	0	0	0	6.26
7:00 PM	4.86	4.86	0	0	0	0	0	0	0	4.86	4.86	4.86
8:00 PM	4.02	4.02	4.02	4.02	0	0	0	0	4.02	4.02	4.02	4.02
9:00 PM	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
10:00 PM	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
11:00 PM	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Monthly Totals	*24.17*	*24.17*	*14.80*	*12.83*	*8.81*	*8.15*	*8.81*	*8.81*	*12.83*	*19.66*	*19.66*	*30.43*

Total **16.09**

APPENDIX I-3. NIGHTTIME TRAFFIC VOLUMES PERCENTAGES IN KENTUCKY FOR URBAN INTERSTATES/PARKWAYS BY HOUR AND MONTH

	January	February	March	April	May	June	July	August	September	October	November	December
MIDNIGHT	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
1:00 AM	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
2:00 AM	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
3:00 AM	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
4:00 AM	0.90	0.90	0.90	0.90	0.90	0	0.90	0.90	0.90	0.90	0.90	0.90
5:00 AM	1.94	1.94	1.94	0	0	0	0	0	0	1.94	1.94	1.94
6:00 AM	4.94	4.94	0	0	0	0	0	0	0	0	0	4.94
7:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
8:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
9:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
10:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
11:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
NOON	0	0	0	0	0	0	0	0	0	0	0	0
1:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
2:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
3:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
4:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
5:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
6:00 PM	0	0	0	0	0	0	0	0	0	0	0	5.92
7:00 PM	4.19	4.19	0	0	0	0	0	0	0	4.19	4.19	4.19
8:00 PM	3.43	3.43	3.43	3.43	0	0	0	0	3.43	3.43	3.43	3.43
9:00 PM	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
10:00 PM	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
11:00 PM	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81
Monthly Totals	*26.30*	*26.30*	*17.17*	*15.23*	*11.80*	*10.90*	*11.80*	*11.80*	*15.23*	*21.36*	*21.36*	*32.22*

Total **18.46**

APPENDIX I-4. NIGHTTIME TRAFFIC VOLUMES PERCENTAGES IN KENTUCKY FOR URBAN OTHER BY HOUR AND MONTH

	January	February	March	April	May	June	July	August	September	October	November	December
MIDNIGHT	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
1:00 AM	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
2:00 AM	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
3:00 AM	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
4:00 AM	0.49	0.49	0.49	0.49	0.49	0	0.49	0.49	0.49	0.49	0.49	0.49
5:00 AM	1.44	1.44	1.44	0	0	0	0	0	0	1.44	1.44	1.44
6:00 AM	3.80	3.80	0	0	0	0	0	0	0	0	0	3.80
7:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
8:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
9:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
10:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
11:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
NOON	0	0	0	0	0	0	0	0	0	0	0	0
1:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
2:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
3:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
4:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
5:00 PM	0	0	0	0	0	0	0	0	0	0	0	0
6:00 PM	0	0	0	0	0	0	0	0	0	0	0	6.21
7:00 PM	4.86	4.86	0	0	0	0	0	0	0	4.86	4.86	4.86
8:00 PM	4.35	4.35	4.35	4.35	0	0	0	0	4.35	4.35	4.35	4.35
9:00 PM	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65	3.65
10:00 PM	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29
11:00 PM	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51
Monthly Totals	*24.34*	*24.34*	*15.68*	*14.24*	*9.89*	*9.40*	*9.89*	*9.89*	*14.24*	*20.54*	*20.54*	*30.55*

Total **16.96**

APPENDIX J. SUMMARY OF ALL 0.3–MILE SPOTS WITH A CRITICAL NUMBER OF 3 (NIGHTTIME CRASHES WITH NO LIGHTING) (2000-2002)

Spot Buildup Analysis

The length is 0.3

The critical number is 3

Total number of spots/sections: 3570

Number of spots/sections with crf >=1: 1276

Total Number of spots/Sections with a CRF > 1 by County

1)	11	41)	29	81)	17
2)	8	42)	13	82)	13
3)	5	43)	12	83)	5
4)	5	44)	2	84)	5
5)	11	45)	17	85)	6
6)	5	46)	4	86)	0
7)	7	47)	15	87)	13
8)	31	48)	4	88)	7
9)	7	49)	20	89)	20
10)	12	50)	6	90)	26
11)	3	51)	22	91)	4
12)	13	52)	10	92)	17
13)	3	53)	1	93)	12
14)	5	54)	25	94)	4
15)	26	55)	3	95)	1
16)	1	56)	12	96)	14
17)	6	57)	24	97)	10
18)	11	58)	7	98)	49
19)	15	59)	20	99)	2
20)	0	60)	11	100)	17
21)	6	61)	24	101)	0
22)	9	62)	6	102)	0
23)	3	63)	12	103)	33
24)	14	64)	2	104)	5
25)	17	65)	0	105)	29
26)	3	66)	4	106)	27
27)	0	67)	7	107)	7
28)	1	68)	3	108)	6
29)	1	69)	10	109)	10
30)	20	70)	4	110)	0
31)	4	71)	10	111)	2
32)	4	72)	7	112)	4
33)	1	73)	48	113)	9
34)	29	74)	8	114)	27
35)	2	75)	5	115)	1
36)	35	76)	21	116)	3
37)	23	77)	4	117)	9
38)	4	78)	14	118)	3
39)	2	79)	20	119)	4
40)	4	80)	9	120)	13

Total Number of Spots/Sections with a CRF > 1 by Highway District

1	116
2	151
3	74
4	110
5	116
6	154
7	170
8	62
9	106
10	37
11	60
12	120

Total number of Crashes Reviewed: 34354

APPENDIX K. INTERSECTIONS WITH THREE OR MORE NIGHTTIME CRASHES (1999 – 2001 DATA)

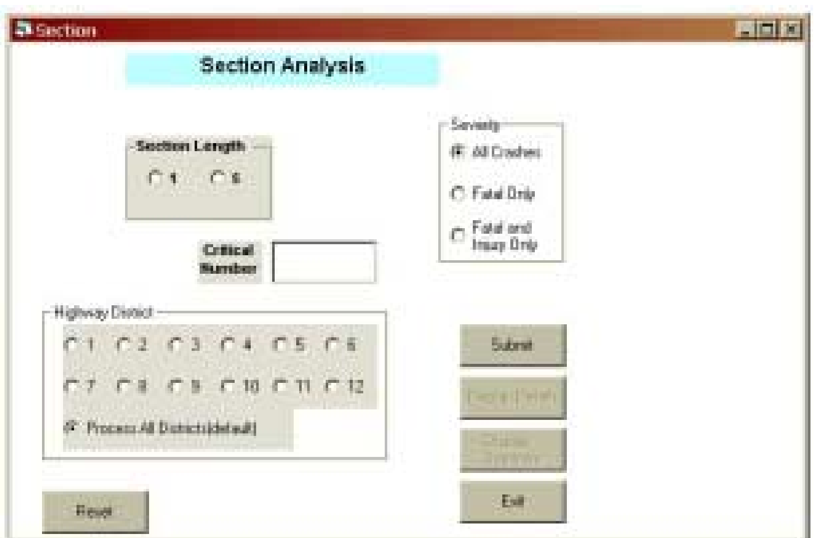
HD	CO	RT	SU	# CRASHES	BMP	EMP	NK	NI	ADT	RU	NL	MT	FC	Cact
1	73	68		6	1.000	1.000	0	1	9330	Rural	4	Unprot	2 PA oth	0.59
5	37	127		5	3.900	3.900	0	4	17229	Rural	4	Unprot	2 PA oth	0.27
1	73	1954		5	2.920	2.920	0	2	6428	Urban	2	None	16 MA	0.71
7	76	421		5	7.980	7.980	0	3	4452	Rural	2	None	6 MA	1.03
7	76	876		5	7.690	7.690	0	5	28422	Urban	4	Curbed	14 PA Non	0.16
6	8	18		4	11.810	11.811	0	0	19000	Urban	4	Unprot	16 MA	0.19
6	19	27		4	10.380	10.380	0	0	28590	Urban	2	Unprot	14 PA Non	0.13
2	30	60		4	18.100	18.100	0	5	13500	Urban	2	Unprot	14 PA Non	0.27
2	30	231		4	8.900	8.900	0	6	9390	Rural	2	None	7 MajC	0.39
7	34	27		4	7.610	7.610	0	0	25900	Urban	4	None	14 PA Non	0.14
7	57	68		4	7.310	7.314	0	0	7556	Rural	2	None	6 MA	0.48
11	61	25	E	4	24.220	24.221	0	7	20367	Rural	4	Unprot	2 PA oth	0.18
8	69	27		4	5.650	5.650	0	6	6621	Rural	2	None	2 PA oth	0.55
1	73	45		4	0.260	0.260	0	3	11435	Rural	4	Unprot	2 PA oth	0.32
1	73	45		4	2.590	2.590	0	1	11435	Rural	4	Unprot	2 PA oth	0.32
1	73	1954		4	3.620	3.622	0	0	6910	Urban	4	Curbed	16 MA	0.53
8	100	27		4	12.300	12.300	0	1	25311	Urban	6	Unprot	14 PA Non	0.14
5	106	55		4	8.030	8.030	0	2	11200	Urban	2	None	14 PA Non	0.33
9	10	60		3	6.550	6.555	0	1	26098	Urban	4	Unprot	14 PA Non	0.11
5	15	44		3	18.600	18.600	0	2	9580	Rural	2	None	7 MajC	0.29
5	15	1020		3	1.780	1.780	0	1	4493	Rural	2	None	7 MajC	0.61
1	18	641		3	10.250	10.250	0	4	16500	Rural	4	Unprot	2 PA oth	0.17
1	18	641		3	11.770	11.770	0	0	16500	Rural	4	Unprot	2 PA oth	0.17
6	19	27		3	4.950	4.952	0	0	10700	Rural	2	None	6 MA	0.26
6	19	27		3	9.890	9.890	0	6	11738	Urban	4	Unprot	14 PA Non	0.23
9	22	7		3	9.590	9.590	0	1	4803	Rural	2	None	6 MA	0.57
12	36	23		3	0.860	0.860	0	3	19720	Rural	4	Unprot	2 PA oth	0.14
12	36	23		3	1.800	1.802	0	7	19583	Rural	4	Unprot	2 PA oth	0.14
1	42	45		3	20.550	20.550	0	1	11855	Rural	4	Unprot	2 PA oth	0.23
1	42	45		3	25.360	25.361	0	0	11855	Rural	4	Unprot	2 PA oth	0.23
4	47	3005		3	0.560	0.562	0	0	9901	Urban	2	None	16 MA	0.28
5	56	31	E	3	5.066	5.066	0	1	29700	Urban	4	Curbed	14 PA Non	0.09
5	56	61		3	2.450	2.450	0	0	28300	Urban	4	None	14 PA Non	0.10
5	56	864		3	9.610	9.614	0	0	29104	Urban	4	Unprot	14 PA Non	0.09
5	56	864		3	10.260	10.260	0	4	29104	Urban	4	Unprot	14 PA Non	0.09
5	56	1932		3	1.120	1.120	0	1	20449	Urban	4	Unprot	16 MA	0.13
5	56	2052		3	0.680	0.680	0	0	31561	Urban	4	None	16 MA	0.09
7	57	27		3	5.800	5.800	2	4	15066	Rural	4	Unprot	2 PA oth	0.18
6	59	1303		3	3.290	3.290	0	0	13870	Urban	2	None	16 MA	0.20
11	63	80		3	8.800	8.801	0	3	9689	Rural	4	Unprot	2 PA oth	0.28
1	73	62		3	12.880	12.881	0	0	13300	Urban	2	None	16 MA	0.21
1	73	1954		3	2.060	2.060	0	1	1593	Rural	2	None	8 MinC	1.72
7	76	52		3	17.770	17.775	0	0	13537	Rural	2	None	7 MajC	0.20
4	90	150		3	1.680	1.680	0	3	11100	Urban	2	Unprot	14 PA Non	0.25
8	100	1674		3	1.900	1.900	0	0	1626	Rural	2	None	8 MinC	1.69
8	102	150		3	8.709	8.709	0	1	7524	Rural	2	None	6 MA	0.36
5	108	55		3	11.270	11.270	0	0	9391	Rural	2	None	6 MA	0.29

APPENDIX L. DESCRIPTION AND USE OF INTERACTIVE NIGHTTIME CRITICAL RATE ANALYSIS PROGRAM

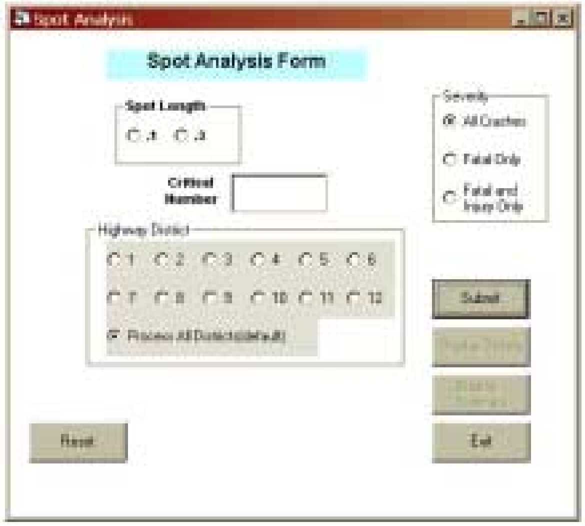
The following is a description of how the software is used to identify high crash locations using the nighttime crash and volume data. This may be used for instruction purposes and to understand the functions of the software.

The program begins with an introduction screen allowing the user to choose either section or spot analysis. The user can click either button to begin with the chosen analysis or choose 'exit' to terminate the program. The following screenshot shows these options.

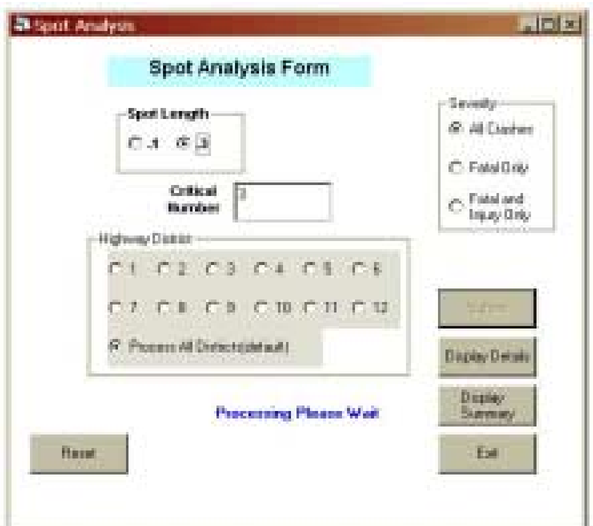
If the user chooses the section analysis a new screen is displayed. The user is prompted for the section length (either 1 or 5 miles) and the critical number (user defined). The user may also choose to analyze data from one specific highway district by simply clicking the appropriate radio button. The default analysis is 'all districts.' Additionally, the user may choose to analyze specific severity classes: All Crashes (default), Fatal Only, or Fatal and Injury Only. The following screenshot displays these options.



If the user chooses the spot analysis a different window is opened. The functions of this analysis are identical to the section analysis with the exception of the spot length. The user now chooses either a 0.1-mile or 0.3-mile spot. The following screenshot displays the spot analysis interface.



The submit button can be clicked after the user selects the appropriate options. The program will process the information. After the locations are determined, two new buttons will be available. The user can now display the results in detail (a Microsoft Excel file will be executed) or in summary (a Microsoft Word document will be executed). The following screenshot shows this interface.



When the results are displayed in detail or summary, the data can be printed, sorted, or saved as with any office document. The form can also be reset to start a new query or exited. An example of the format of the “display details” is given in Figure 3 and an example of the “display summary” format is given in Figure 2.