Effects of Roadway Lighting Level on the Traffic and Pedestrian Safety

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Abstract

The level of roadway lighting is an important factor for the safety of roadways during the nighttime, especially for pedestrians. Past studies have shown that over fifty percent of pedestrian crashes occurred during nighttime. Most of these were fatal and severe injury crashes. These results make it clear that proper design and timely maintenance of street lighting will definitely help improve the safety of the roadway system. To evaluate the roadway lighting systems and maintain their functionality, it is essential to perform field lighting measurements. In this study, a mobile lighting measurement system was developed and installed in a test vehicle to collect illuminance data along a corridor of U.S. 19 in Pinellas County, Florida. The night time pedestrian crash data were collected for a three year period. The preliminary study shows that the frequency of night time pedestrian crash at low lighting level segments is much higher than those segments with a high illuminance level.


INTRODUCTION

Roadway lighting is one of the key elements of roadway system in regards to safety. A Federal Highway Administration study (1) reported that, in the United States, nighttime crash rates are five times higher than daytime crash rates. More to the point, approximately 50 percent of the fatalities occur during the nighttime and only 25 percent of the vehicle miles are driven during the nighttime. These statistics clearly indicate that the improvements to nighttime driving environment might help reduce nighttime crash rates. In the past, many studies were conducted to investigate the impacts of installation of street lighting on roadway safety. Most studies indicated that roadway safety was positively impacted in the way that reduced the number of crashes, injuries, and fatalities.

Proper design and timely maintenance are two vital factors for street lighting systems to be effective and beneficial to road users. The design itself needs to consider many factors and requires expertise in many areas, such as civil, electrical, and lighting engineering. The newly installed system should be evaluated to assure that roadway lighting levels meets the design standards. Initial design might be perfect; however, as time passes, the system may not work as well as when initially installed. In order to maintain the effectiveness and functionality of street lighting systems after design, it should be inspected to assess how well the system is maintained.

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Currently, roadway lighting levels are often measured with handheld light meters. After roadway lighting systems are designed, the design programs can establish a grid on the pavement surface and then use the estimated illuminance values at these points on the grid to determine the average value and the uniformity ratios (avg/min and max/min). To manually collect illuminance data using handheld light meters on all of the roadways in District 7 represents an enormous data collection task. This data collection effort would also put the people operating the light meters in the middle of the roadways during nighttime low-lighting conditions, creating a potential safety concern for both data collection personnel and other roadway users.

In order to address these concerns, a new measurement strategy was developed for collecting the lighting data in a manner that minimizes the risk exposure for the data collection personnel. The original idea is to measure the lighting level on a moving vehicle using a combination of lighting meters and Distance Measurement Instrument (DMI). The illuminance data recorded by a light meter will match the location data from GPS or DMI.

An additional area of concern is maintaining adequate lighting levels in crosswalk areas for the safety of pedestrians. Similarly, to the work being done for the automobile, strategies also must be developed to measure the light levels on pedestrian facilities in a manner that is safe and efficient.

LITERATURE REVIEW
Past studies, research projects, standards and guidelines related to the street lighting data collection, design and the evaluation of the roadway lighting systems were reviewed and summarized.

Lighting System Design
Design of a roadway lighting system is a joint effort of engineers from various areas of specialization. Gazzar (2) divided the design process into four steps to help the designer come up with better decisions. The four design steps are: Step 1: An initial study should be conducted to identify the roadway elements and also specifications of the roadway; Step 2: Fixture and luminaire selection requires one to be familiar with detailed specifications of the equipment available in the market. Step 3: The location of the fixtures and poles can be determined by use of readily available software for this purpose. Step 4: Verification of the lighting design criteria can also be conducted by the design software. There are three design criteria considered for roadway lighting systems design, which are explained in the following subchapters.

Roadway Lighting Design Criteria
Illuminance, luminance, and small target visibility are three criteria for verification of roadway lighting design in the standard practice. Illuminance is defined as the amount of light flux that falls on the surface at a certain distance from the light source. Luminance is another commonly used measurement of lighting level for the design and evaluation of
roadway lighting systems. Small target visibility is a relatively new approach to improve the safety of drivers.

**Illumination Measurement and Safety Impacts**

Evaluation of roadway lighting systems is an important task to ensure that the system works at the desired level. Evaluation methodology is usually selected based on the standards required for the lighting system. The timing of the evaluation is another factor to take into consideration. Initial evaluations are often conducted right after installation. The evaluation results will not be affected by some light depreciation factors such as dirt and aging of luminaires. However, evaluation of a system after years of operation will reveal the effects of light depreciation factors. In the literature review, many guidelines were found for the design of roadway lighting systems. Many commercial software were especially developed for this purpose. However, few guidelines and standards are available for evaluation purposes.

In 1988, Zimmer (5) developed “A Mobile Illumination Evaluation System” at the Texas Transportation Institute. The main purpose of the system was to collect illumination data for high mast lighting systems. The illumination method was selected for data collection. The system was installed in a test vehicle and illuminance measurements are taken by a light meter placed on top of the vehicle. Illumination data were taken on each lane of roadways to compute the system characteristics. The system developed for that study could collect data at reasonable speeds. However, the technology for lighting measurements and computers at that time were not well developed. Currently, the light meters are more accurate and the laptop computers are faster. For high mast lighting systems, luminaires are relatively higher than conventional roadway lighting. The measurements may not be affected by the height of the light meter sensor as in conventional roadway lighting measurements. The study also did not develop a methodology to convert the illuminance on the top of vehicles to six inches above the pavement.

A study conducted by Green et al. (6) at the Kentucky Transportation Center of the University of Kentucky, investigated the relationship between illumination levels and nighttime crashes. Illumination data was collected with handheld light meters at the identified locations. The results of the study indicated that nighttime crashes were reduced by 45 percent after installing street lighting at the intersections. Additionally, the study included a survey of States related to their roadway lighting standards. The survey results showed that most States use the information from either AASHTO “An Informational Guide for Roadway Lighting” or “American Standard Practice for Roadway Lighting” (ANSI/IESNA RP-8-00) as their standards.

Three methods have been used to evaluate roadway lighting level. Illumination method is mostly used in field evaluation and recommended by national and state lighting design guidelines. An early study has indicated that the idea of developing a mobile illuminance measurement system is feasible. In addition, past studies showed that safety can be improved by adding or improving street lighting.
METHODOLOGY

Based on literature review, illuminance method is found to be the most suitable method for field evaluation of roadway lighting systems. Currently, illuminance data are manually collected by the use of handheld light meters. In this project, a mobile lighting measurement system will be developed to eliminate the risk of personnel and reduce the labor costs.

System Development

Before system development, it is essential to understand what kind of data is needed for collection. The results of literature review indicated that the illuminance is one of the main criteria for evaluation of roadway lighting level. The illuminance method requires measurement of illuminance (lux or foot candle) values at some desired points. Collecting coordinates of desired points and corresponding illuminance data simultaneously and accurately is a challenging task. If both coordinates and illuminance data were collected separately, it would be difficult to match them. Due to the above reasons, it was necessary to develop a mobile measurement system that can collect both distance and illumination data at the same time. After considering safety and speed issues, it was decided that the system should be installed on top of a vehicle. The system installed in vehicle could collect illumination data at a desired distance interval and a reasonable speed of a test vehicle.

After the initial design, the project team determined the necessity of the following elements:

- Light Meter
- Distance Measurement Instrument (DMI)
- Laptop Computer
- Connections between the computer, light meter and DMI
- Software to collect, store and analyze data

DATA COLLECTION AND ANALYSIS

The study corridor is located along U.S. 19 (SR 55) in Pinellas County from River Watch Boulevard in North Pinellas County to 54th Avenue South spanning 32 miles. The U.S. 19 corridor in Pinellas County has more total pedestrian crashes than any other roadway within the county.

Crash Data

The datasets used for the study include: FDOT U.S.19 pedestrian crashes 2000-2005; FDOT District 7 pedestrian crashes 2000-2005; and FDOT district 7 crash data management system.

FDOT crash data includes only crashes occurring along the State Highway System and typically is limited to long form crash data which include the more sever crashes. As such, the crash data for this study do not include most minor “fender-bender” crashes.
Likewise, non-injury pedestrian crashes tend to be underreported. Crashes that occur on frontage roads along U.S. 19 are also included in the data set.

Three years of pedestrian accident data (2003-2005) were collected to adequately identify the corridor’s safety problems and evaluate the relationship between the lighting intensity and crash frequency. The hard copies of pedestrian crash record (2003-2005) were reviewed. There are a total of 199 pedestrian crashes.

**Illumination Data**

The illumination along the corridor was recorded using a developed mobile lighting measurement system, a combination of a light meter and a Distance Measurement Instrument (DMI). The illumination was recorded at 40 feet intervals on the most right side lane of U.S. 19.

**Data Analysis**

Along the 32 mile stretch of U.S. 19 in Pinellas County, according to the FDOT crash database, 105 pedestrian crashes of the total 199 pedestrian crashes during the six year period occurred at night. Also, only 18 of these 105 crashes occurred at locations without streetlights, and the remaining 87 crashes occurred at locations where streetlights were present. Therefore, the lighting conditions of the crash site locations were analyzed.

Figure 1 shows the frequency of crashes and lighting level as measured in lux. Illuminance is the amount of light reaching the roadway surface, measured in foot candles (lumens/ft²) or lux (lumens/m²).

![Figure 1 Number of Pedestrian Accidents at Night for Different Lighting Conditions](image)

The lighting level was measured using a handheld light-meter (EXTECH 401036) fixed to the top of a vehicle (about four feet above the pavement) moving at an average speed.
of 30 mph. The measurement was taken in the right lane of the roadway. As shown in Figure 8, lighting condition at 50 crash site locations was below 10 lux. According to the preliminary measurement of lighting level on U.S. 19, night time pedestrian crashes occur more often at lower lighting level conditions as compared to higher lighting level conditions.

CONCLUSION

The mobile lighting measurement system developed by this research can be used to collect massive light data in short periods of time. The new system will not only reduce the cost of the future data collection efforts, but also improve the safety of the data collection personnel. The preliminary research showed that there is a possible relationship between the night time crashes and roadway lighting level. The next phase of the project will collect the illuminance along 250 miles state highway. And also the crash data will be collected to investigate if there is a direct relationship between the lighting level and night time crashes.

ACKNOWLEDGEMENT

This study was funded by the Florida Department of Transportation, District 7. The authors also wish to acknowledge the contribution of their former colleague Mr. Larry Hagen and graduate student Fatih Pirincciooglu at the Center for Urban Transportation Research of the University of South Florida.

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