TECH BRIEF
February 2018

# Safety Evaluation of Destination Lighting at Stop-Controlled Cross Intersections


## Authors

**Shauna L. Hallmark**
Director, Institute for Transportation
(orcid.org/0000-0002-7304-8430)
515-294-5249, shallmar@iastate.edu

**Amrita Goswamy**
Graduate Research Assistant
(orcid.org/0000-0003-0113-3094)

**Theresa Litteral**
Research Scientist, Institute for Transportation
(orcid.org/0000-0003-0113-3094)

**Michael Pawlovich**
Lecturer, South Dakota State University
(orcid.org/0000-0001-9659-0348)



## Sponsors

Iowa Department of Transportation
Midwest Transportation Center
U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology (Part of DTRT13-G-UTC37)
Federal Highway Administration
(InTrans Project 14-509)

## For More Information

Center for Transportation Research and Education, Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103 / intrans.iastate.edu

ctre
Center for Transportation Research and Education

MIDWEST TRANSPORTATION CENTER MTC

IOWA STATE UNIVERSITY
Institute for Transportation


## Background

Unlit or inadequately lit intersections reduce the ability of drivers to recognize upcoming intersections during nighttime hours. Drivers also face difficulty in properly negotiating the intersection because lack of adequate lighting increases the likelihood of not detecting conflicting vehicles or pedestrians. In general, the nighttime crash rate is about 1.6 times that of the daytime crash rate (Hasson and Lutkevich 2002, Opiela et al. 2003).

Standards and best practices are available for full-scale lighting of intersections. However, addition of lighting structures and wiring can be a significant cost for rural agencies and may not be justified for lower traffic volumes. One solution commonly used in Iowa and other states is destination lighting. Destination lighting only guides drivers to the intersection and may not provide sufficient lighting to increase visibility (Carstens and Berns 1984).

Destination lighting is intended to visually mark an upcoming intersection so drivers are alerted to its presence. In most cases, a single light (or head) is placed on the nearest utility pole, which reduces the need for additional structures and wiring. Destination lighting is typically placed at one approach but it is not unusual for lights to be placed proximate to multiple approaches.

Although destination lighting does not provide a full lighting footprint, it does provide some illumination for the intersection. Destination lighting can be a good countermeasure for rural intersections where nighttime crashes involve stop sign running or a failure to yield.

The Iowa Department of Transportation (DOT) Traffic and Safety Manual provides lighting warrants for full lighting and destination lighting. According to the manual, destination lighting should be placed at intersections with approximately

David Veneziano/Iowa Local Technical Assistance Program (LTAP) at InTrans

***Destination lighting visually marks an upcoming intersection; in most cases, a single light is placed on the nearest utility pole at one approach, reducing the need for additional structures***

more than 1,750 entering vehicles in comparison to 3,500 average daily traffic (ADT) for full lighting (Iowa DOT 2001). Destination lighting should also be considered when the night-to-day crash ratio is 1.0 or greater with at least two reportable nighttime crashes in a five-year period (Iowa DOT 2001).

## Problem Statement

Although various studies have assessed the safety of intersection lighting, the impact of destination lighting has not been well studied.

## Project Objective

The objective of this research was to examine the relationship between traffic, crash, and roadway data for stop-controlled cross intersections provided with destination lighting in Iowa.

## Previous Studies

A summary of studies that have evaluated intersection lighting is shown in Table 1.

In most of the studies, the type of lighting (i.e., regular versus destination) was not indicated. As a result, although lighting in general has shown a positive safety benefit, the impact of destination lighting is still relatively unknown.

## Research Description and Scope

Crash frequency models were developed to identify the safety effectiveness of providing destination lighting at cross intersections. Since destination lighting is significantly less expensive for rural agencies to install, this study evaluated in-place destination lighting to assess its impacts on rural intersection crashes.

## Data Collection

A database was developed that included traffic and geometric characteristics of the intersections of interest. The traffic, roadway, and geometric data of each intersection were merged with crash frequency data over a 10-year analysis period from 2006 to 2016.

Table 1. Summary of previous lighting studies

| Study | Sample and Type | Crashes | Impact |
|---|---|---|---|
| Carstens and Berns 1984 | Before-after comparison of 91 secondary road intersections and comparison of 102 lighted with 102 unlighted intersections | Total, nighttime and daytime crash rates | No reduction and differences in crashes observed |
| Isebrands et al. 2010 | 33 intersections with 3 years of before-and-after data | Nighttime crashes | -37% |
| Isebrands et.al. 2006 | 48 rural intersections | Nighttime crashes per intersection | -13% |
| | | Ratio of night to total crashes | -21% |
| | | Ratio of night-to-day crashes | -36% |
| Preston and Schoenecker 1999 | A before/after analysis of 12 intersections | Nighttime crash rate | -40% |
| Bullough et al. 2013 | Intersections in Minnesota | Night-to-day crash ratio | -12% |
| Donnell et al. 2010 | Intersections in Minnesota | Night crash frequency | -7.6% |
| | | Night-to-day crash ratio | -12% |
| Bruneau and Morin 2005 | 376 sites | All | -29% to -39% |
| | | PDO crashes | -37% to -48% |
| Walker and Roberts 1976 | 47 rural at-grade intersections in Iowa | Average overall nighttime crashes | -49% |
| Lipinski and Wortman 1978 | Rural at-grade intersections in Illinois | Overall night-to-day crash ratio | -22% |
| | | Nighttime crash rate | -45% |
| | | Total crash rate | -35% |
| Wortman and Lipinski 1974 | Rural at-grade intersections in Illinois | Night crashes | -30% |

### Identification of Sites

The Institute of Transportation (InTrans) and the Iowa DOT developed an intersection database for the state that also contained information about all rural and urban intersection characteristics in Iowa. Intersection locations on most public roadways were identified and associated characteristics, such as type of traffic control (i.e., stop, yield, and signal), presence of overhead lighting, and so forth, were coded.

A total of 309 intersections with destination lighting were identified with 306 of them at four-legged intersections and three of them at T-intersections. Due to the extremely small number of T-intersections, this study concentrated on four-legged intersections only.

The locations identified were checked against sources such as Google Street View, Microsoft Birdseye, and Google Aerial View to confirm the presence of destination lighting. Intersection characteristics such as number of approaches and intersection angle were also extracted. Characteristics, specific to individual approaches such as roadway surface type (i.e., gravel, paved), advance stop sign rumble strips, and advance signing were recorded. Presence of destination lighting and other intersection or approach characteristics were confirmed using multiple data sources.

Control sites with no lighting that had similar roadway characteristics were identified using a similar methodology. The first step in identifying candidate control sites was to check for intersections near each treatment intersection. A control intersection was manually selected by using ArcGIS to match it to a corresponding treatment intersection. One control location was selected for each treatment intersection using the following important variables: type of intersection, proximity, volume, and type of channelization or presence of rumble strips or countermeasures (such as raised median).

### Traffic Data

The Iowa DOT maintains a roadway inventory, the Geographic Information Management System (GIMS) database, which was used to obtain the traffic volume data for each of the approach roadways for the intersections. Daily entering vehicles was calculated for the middle year for the 10-year study period of 2006 to 2016.

### Iowa Crash Database

The Iowa DOT maintains a historical crash database that includes geographically referenced information detailing the driver, vehicle, roadway, and environmental factors associated with each crash reported by law enforcement. Crash-level data provided the location, date, severity level, and other general information about each crash. Crashes occurring within 250 feet of each intersection were obtained for 2006 to 2016 (10 years). Various records were consulted to ensure lighting was present at treatment sites during the entire 10-year study period.

Crash severity levels were as follows: fatal, major, injury, minor, property-damage-only (PDO) crashes, and unknown. Time of crash was used to identify nighttime crashes. Crashes at dusk and dawn were not included in the calculation of nighttime crashes.

## Methodology and Results

The total number of nighttime and daytime crashes were determined for each of the treatment and control sites. An original model was developed to develop a crash modification factor (CMF) for nighttime crashes. It was not possible to determine when lighting had been installed, so a cross-sectional analysis was conducted rather than a before-and-after analysis. However, the results were not conclusive. It was determined this was likely due to the fact that lighting was installed at locations which had a nighttime crash problem which differed from control intersections.

A preliminary simple comparison of the data indicated that there were significant differences in the ratio of day to night crashes at treatment versus control intersections suggesting the treatment is effective at night. This method has been used by others to compare the relative safety of lighting such as Jackett and Frith (2013) and Bhagavathula et al. (2015), who used the nighttime to daytime crash ratio to assess road luminance.

As noted in Table 2, the night-to-day crash ratio for treatment sites with destination lighting was 0.19 while the ratio for control sites was 0.38.

Table 2. Night-to-day crash ratios

| Site Type | Daytime Crashes (D) | Nighttime Crashes (N) | N/D |
|---|---|---|---|
| Control | 329 | 126 | 0.38 |
| Treatment | 462 | 87 | 0.19 |

This indicated about 0.19 nighttime crashes result for every daytime crash at treatment sites while about 0.38 nighttime crashes occur at control sites for every daytime crash. As a result, this simple comparison shows that the ratio of night-to-day crashes at treatment sites is about 19 percent lower than for control sites.

Cross-sectional models were developed for target intersection-related crashes. A target crash was defined as any non-animal, intersection-related crash. Animal crashes were not included since presence of an animal is an unexpected event and lighting has not historically been used to address animal crashes.

Models were developed for all injury severities (fatal, major, injury, minor), PDO crashes, and unknown. Cross-sectional crash models using negative binomial generalized linear regression analysis were developed with an indicator variable for presence and absence of destination lighting. Once the databases were compiled, a series of statistical analyses were conducted to ascertain how crashes were affected by traffic and geometric and site characteristics.

Separate models for nighttime and daytime crashes were evaluated. The parameter estimates of the statistically significant variables (at 95 percent confidence level) in the cross-sectional models are shown in Table 3. The standard errors and p-values are also provided for the parameter estimates; or, in other words, beta estimates are also shown in Table 3.

A one percent increase in major road annual average daily traffic (AADT) was associated with approximately a 0.4 to 1.2 percent increase in crash frequency. As noted, the results suggest that the presence of destination lighting is associated with a 33–39 percent increase in daytime crashes across all models, and an 18–33 percent reduction in nighttime crashes.

Nighttime injury crashes decreased by 24 percent and total nighttime crashes decreased by 33 percent. PDO crashes were reduced by 18 percent. The correlation between increased daytime crashes and destination lighting likely suggests the treatment was applied at locations with a higher number of crashes.

## Discussion

This study examined the safety effectiveness of the installation of destination lighting at stop-controlled cross intersections in rural Iowa. Preliminary night-to-day crash ratios showed the night-to-day crash ratio for treatment sites with destination lighting was 0.19 while the ratio for control sites was 0.38. This indicated about 0.19 nighttime crashes result for every daytime crash at treatment sites while about 0.38 nighttime crashes occur at control sites for every daytime crash. Thus, this simple comparison showed that the ratio of night-to-day crashes at treatment sites is about 19 percent lower than for control sites.

Various factors affecting the frequency of crashes occurring at the study sites were also analyzed. A caliper width technique for propensity-score matching was used to match treatment and control sites in this study. Crash frequency data were analyzed using negative binomial regression models. The presence of destination lighting was associated with a 33–39 percent increase in daytime crashes across all models, and with an 18–33 percent reduction in nighttime crashes. This suggests, as expected, that destination lighting has been utilized at locations that exhibited crash problems. As a result, destination lighting provided a significant safety benefit.

Table 3. Nighttime and daytime crash frequency models

| Crash Type | Variable | Nighttime Crashes | | | Daytime Crashes | | |
|---|---|---|---|---|---|---|---|
| | | Parameter Estimate | Std. Error | p-value | Parameter Estimate | Std. Error | p-value |
| **Total** | (Intercept) | -7.441 | 0.775 | 0.000 | -7.404 | 0.499 | 0.000 |
| | **Destination Lighting (Treatment)** | **-0.406** | **0.154** | **0.008** | **0.306** | **0.101** | **0.002** |
| | LnDEV | 0.960 | 0.103 | 0.000 | 1.035 | 0.066 | 0.000 |
| | Paved major paved minor road | 0.337 | 0.157 | 0.032 | 0.651 | 0.101 | 0.000 |
| | One exclusive left turn present | -0.769 | 0.431 | 0.074 | NA | NA | NA |
| | All way stop | -1.327 | 1.061 | 0.211 | -0.408 | 0.521 | 0.434 |
| | Two-way stop-controlled | -0.399 | 0.233 | 0.086 | -0.243 | 0.160 | 0.128 |
| | Alpha* | 0.206 | 0.134 | 0.158 | 0.322 | 0.062 | 0.000 |
| **Injury** | (Intercept) | -7.208 | 1.524 | 0.000 | -7.273 | 0.528 | 0.000 |
| | **Destination Lighting (Treatment)** | **-0.277** | **0.341** | **0.417** | **0.336** | **0.136** | **0.013** |
| | LnDEV | 0.777 | 0.211 | 0.000 | 0.879 | 0.082 | 0.000 |
| | Paved major paved minor road | 0.403 | 0.374 | 0.282 | 0.792 | 0.136 | 0.000 |
| | Alpha* | 4.693 | 1.796 | 0.009 | 0.400 | 0.114 | 0.000 |
| **PDO** | (Intercept) | -2.500 | 0.469 | 0.000 | -9.264 | 0.785 | 0.000 |
| | **Destination Lighting (Treatment)** | **-0.209** | **0.101** | **0.039** | **0.287** | **0.135** | **0.034** |
| | LnDEV | 0.357 | 0.063 | 0.000 | 1.172 | 0.101 | 0.000 |
| | Paved major paved minor road | NA | NA | NA | 0.538 | 0.144 | 0.000 |
| | One exclusive right turn present | -0.169 | 0.134 | 0.207 | NA | NA | NA |
| | Alpha* | 0.226 | 0.001 | 0.979 | 0.495 | 0.124 | 0.000 |

*Over-dispersion factor
PDO: Property damage only

Nighttime injury crashes decreased by 24 percent and total nighttime crashes decreased by 33 percent. Property damage crashes decreased by 18 percent.

The results of this study yielded insights into the importance of providing destination lighting at stop-controlled cross intersections. Moving forward, the extensive databases developed as a part of this study may also be supplemented with additional information, such as shoulder and guardrail information. As intersections continue to be an emphasis area for improving safety, the identification of crash modification factors will allow for the proactive and cost-effective implementation of various safety measures.

## Acknowledgments

The team would like to thank the Iowa DOT, the Midwest Transportation Center, and the U.S. DOT Office of the Assistant Secretary for Research and Technology (USDOT/OST-R) for sponsoring this research and to acknowledge that the Iowa DOT used FHWA state planning and research funds to help fund this work.

## References

Bhagavathula, R., R. Gibbons, and C. Edwards. 2015. Relationship between Roadway Illumination Level and Nighttime Rural Intersection Safety. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2485, pp. 8–15.

Bruneau, J-F. and D. Morin. 2005. Standard and Nonstandard Roadway Lighting Compared with Darkness at Rural Intersections. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1918, pp. 116–122.

Bullogh, J. D., E. T. Donnell, and M. S. Rea. 2013. To Illuminate or Not to Illuminate: Roadway Lighting as It Affects Traffic Safety at Intersections. *Accident Analysis and Prevention*. Vol. 53, pp. 65–77.

Carstens, R. L. and L. D. Berns. 1984. *Roadway Lighting on Secondary Roads in Iowa*. Engineering Research Institute, Iowa State University, Ames, IA.

Donnell, E. T., R. J. Porter, and V. N. Shankar. 2010. A Framework for Estimating the Safety Effects of Roadway Lighting at Intersections. *Safety Science*, Vol. 48, No. 10, pp. 1436–1444.

Hasson, P. and P. Lutkevich. 2002. Roadway Lighting Revisited. *Public Roads*. Vol. 65, No. 6.

Iowa DOT. 2001. *Traffic and Safety Manual*, Chapter 6. December. Iowa Department of Transportation, Office of Traffic and Safety, Ames, IA.

Isebrands, H., S. Hallmark, W. Li, T. McDonald, H. Preston, and R. Storm. 2010. Roadway Lighting Shows Safety Benefits at Rural Intersections. *Journal of Transportation Engineering*, Vol. 136, No. 11, pp. 949–955.

Isebrands, H., S. Hallmark, Z. Hans, T. McDonald, H. Preston, and R. Storm. 2006. *Safety Impacts of Street Lighting at Isolated Rural Intersections - Part II*. Center for Transportation Research and Education, Iowa State University, Ames, IA.

Jackett, M. and W. Frith. 2013. Quantifying the Impact of Road Lighting on Road Safety—A New Zealand Study. *International Association of Traffic and Safety Sciences (IATSS) Research*, Vol. 36, No. 2, pp. 139–145.

Lipinski, M. E. and R. H. Wortman. Effect of Illumination on Rural At-Grade Intersection Accidents. *Transportation Research Record: Journal of the Transportation Research Board*, No. 611, pp. 25–27.

Opiela, K. S., C. K. Anderson, and G. Schertz. 2003. Driving After Dark. *Public Roads*. Vol. 66, No. 4.

Preston, H. and T. Schoenecker. 1999. *Safety Impacts of Street Lighting at Rural Intersections*. Minnesota Department of Transportation, St. Paul, MN.

Walker, F. W. and S. E. Roberts. 1976. Influence of Lighting on Accident Frequency at Highway Intersections. *Transportation Research Record: Journal of the Transportation Research Board*, No. 562, pp. 73–77.

Wortman, R. H. and M. E. Lipinski. 1974. *Rural At-Grade Intersection Illumination*. Department of Civil Engineering and Highway Traffic Safety Center, University of Illinois Urbana-Champaign, Urbana, IL.

**About the Center for Transportation Research and Education**

The mission of the Center for Transportation Research and Education (CTRE) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, reliability, and sustainability while improving the learning environment of students, faculty, and staff in transportation-related fields.

**About the Midwest Transportation Center**

The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC) sponsored by the U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology (USDOT/OST-R). The mission of the UTC program is to advance U.S. technology and expertise in the many disciplines comprising transportation through the mechanisms of education, research, and technology transfer at university-based centers of excellence. Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.