



**Summary of a Literature Review on Bridge Lighting**  
**January, 2008**

Key Findings:

- No literature was found that specifically addresses the safety impacts of lighting bridges on highways with no lighting.
- Janoff (Transportation Research Record 1172) studied the effect of low-mounted, lineal lighting (of San Mateo Bridge) on night-time safety. He concluded that lineal-type of lighting adversely affected night-time safety and replacing it with conventional overhead lighting promotes a safer nighttime environment.
- There have been studies on the safety benefits of lighting isolated rural intersections and highways. Although the findings differ about the magnitude of safety improvements, all of the studies conclude that lighting increases safety (i.e., decreases the crash rates).
- Several studies compared continuous lighting of highways with partial lighting (lighting only the interchanges) and no lighting. With safety as the primary variable, the findings are consistent: continuous lighting is better than partial lighting and partial lighting is better than no lighting.
- There have been several studies (mostly from 70s) about the effect of “Transient Visual Adaptation (TVA)” or “Transitional Adaptation” on human perception. TVA can cause visibility loss or produce a “black-out” effect in drivers. These issues focus on the human factors side and the information from these studies should be considered in designing the lighting system.

Conclusion – lighting provides a safety improvement in nearly all conditions. The magnitude of the safety improvement varies by condition.

**Bibliography**

Title: Human Factors in Traffic Safety, Second Edition  
Accession No: 01055902  
Authors: Dewar, Robert  
Olson, Paul  
Corp. Authors  
/ Publisher: Lawyers & Judges Publishing Company, Incorporated  
P.O. Box 30040  
Tucson, AZ 85751-0040 USA  
Publication Date: 20070000  
Edition: Second Edition  
Description: 549p; Figures; Photos; References; Tables  
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Languages: English

Abstract: This book presents the many components of human factors in highway traffic safety. It is comprised of 24 chapters, most of which are divided among 4 sections, as follows: Chapter 1. Introduction; PART I: The Driver - Chapter 2. Perception and Information Processing; Chapter 3. Driver Perception-Response Time; Chapter 4. Where Do Drivers Look While Driving (and for How Long)?; Chapter 5. Individual Differences; Chapter 6. Fatigue and Driving; Chapter 7. Alcohol and Drugs; Chapter 8. Age Differences--Drivers Young and Old; Chapter 9. Neuropsychological, Medical and Psychiatric Disorders and Motor Vehicle Operations; Chapter 10. Driver Distraction; Chapter 11. Driver Education, Training, and Licensing; PART II: The Vehicle - Chapter 12. Vehicle Design; Chapter 13. Visibility with Motor Vehicle Headlamps; PART III: The Roadway Environment - Chapter 14. Roadway Design; Chapter 15. Traffic Control Devices; Chapter 16. Visibility Under Roadway Lighting; Chapter 17. Environmental Factors; Chapter 18. Railroad Grade Crossing Accidents; Chapter 19. Highway Work Zones; PART IV: Accident Causation and Remediation - Chapter 20. Pedestrians and Bicyclists; Chapter 21. Left-Turn and Gap Acceptance Crashes; Chapter 22. Single-Vehicle Accidents; Chapter 23. Eyewitnesses to Accidents - The Factors that Determine Accuracy; and Chapter 24. Human Factors in Traffic Accident Litigation.

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Title Roadway Lighting

Accession No 01002918

Authors King, L Ellis

Corp. Authors

/ Publisher Institute of Transportation Engineers

Editors Robertson, H D; Hummer, J E; NELSON, D C

Publication Date 19940000

Description pp 296-308; Figures; References(13); Tables(5)

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Languages English

Abstract This chapter describes how the ability to see is essential for the safe and efficient flow of traffic on highways. However, in many instances, limitations of the human eye prevent vehicle headlights alone from completely satisfying visual nighttime driving requirements. Fixed roadway lighting supplements vehicle headlights by extending the visibility range both longitudinally and laterally, thus aid the driver by providing earlier warning of hazards on or near the roadway. Previous research has shown that the nighttime accident rate can be reduced by the provision of adequate lighting. Lighting defines the roadway geometrics, such as the edge of pavement, curves, dead ends, and illuminates obstructions in or near the roadway, including channelization islands, bridge piers, and parked cars. Lighting allows the driver to see a pedestrian in the roadway beyond the headlight beam and even before the pedestrian enters the road. It also aids pedestrians by illuminating obstacles on the sidewalk and roadway in their vicinity. Lighting raises the surrounding brightness level to which the driver's eyes adapt and it also increases the driver's contrast sensitivity, which results in an overall improvement in the driver's ability to see. Fixed roadway lighting also contributes to a more pleasant and comfortable night driving environment, which in turn, reduces driver fatigue and improves driver efficiency. Lighting is also an aid to police surveillance, and a reduction in street crimes may be experienced following installation of improved street illumination.

Supplemental

Information This book was reprinted in 2000 by the Institute of Transportation Engineers.

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Title HOW TO DESIGN AND MAINTAIN BRIDGE LIGHTING

Accession No 00485287

Journal Title Public Works Vol. 120 No. 7

Corp. Authors

/ Publisher Public Works Journal Corporation ; Public Works Journal Corporation

Publication Date 19890600

Description p. 64-67; Photos(2)

Abstract This article provides some basic guidelines in the design of bridge lighting. The guidelines relate to visibility, selection of poles and lamps, floodlighting, and minimizing glare. Visibility of drivers is the first and most important goal. The equipment selected should be sturdy, having been designed and tested for use under severe vibration and in corrosive atmospheres. Poles are chosen with local wind conditions in mind. High-pressure sodium (HPS) lamps are excellent for bridge lighting as they are energy efficient and provide the most light for each watt of electricity. Maintenance is simplified if lighting components are standard and off-the-shelf. Floodlighting must be placed on rigid structural supports in locations readily accessible with standard maintenance equipment. A common technique in bridge floodlighting is to recreate the daytime effect of light and shadow. Glare can be minimized by using narrow beam floodlights and aiming them on-site. A glare shield reduces stray light even more.

TRT Terms Access ; Bridges ; Glare ; Guidelines ; Lighting ; Lighting equipment ; Location ; Sodium vapor lamps ; Visibility

Other Terms Floodlighting; Locating; Selecting; Sodium lamps

Subject Areas I24 Design of bridges and retaining walls; H25 STRUCTURES DESIGN AND PERFORMANCE

Availability Public Works Journal Corporation

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Title TRAFFIC ACCIDENT ANALYSIS AND ROADWAY VISIBILITY

Accession No 00610220

Journal Title Transportation Research Record No. 1172

Corp. Authors

/ Publisher Transportation Research Board

Publication Date 19880000

Description 103 p.; Figures; Photos; References; Tables

Abstract This Transportation Research Board publication contains the following papers: Assessment of Existing General Purpose Data Bases for Highway Safety Analysis, K.K. Mak, J.G. Viner, and L.I. Griffin, III; Accident Data as a Tool for Highway Risk Management, D.S. Turner and C.W. Colson; Generalized Loglinear Models of Truck Accident Rates, F.F. Saccomanno and C. Buyco; Estimation of Wet Pavement Exposure from Available Weather Records, D.W. Harwood, R.R. Blackburn, D.F. Kibler, and B.T. Kulakowski; Evaluation of the Accident Rates of Male and Female Drivers, A. Polus, I. Hocherman, and E. Efrat; Highway Accidents and the Older Driver, F.X. McKelvey, T.L. Maleck, N. Stamatiadis, and D.K. Hardy;

Injury Accident Prediction Models for Signalized Intersections, M. Y-K. Lau and A.D. May, Jr.; A Mobile Illumination Evaluation System, R.A. Zimmer; Fog Mitigation Update: Fog Mitigation Measures as Applied to Highway Bridge Structures, C.B. Potash and J.R. Brown; Optimization of Post Delineator Placement from a Visibility Point of View, H.T. Zwahlen, M.E. Miller, M. Khan, and R. Dunn; **Effect of Bridge Lighting on Nighttime Traffic Safety, M.S. Janoff**; and Driver Decision Making at Traffic Signals, R. van der Horst.

TRT Terms Accident analysis ; Accident exposure ; Accident rates ; Aged drivers ; Databases ; Drivers ; Females ; Fog ; Forecasting ; Highway bridges ; Highway safety ; Injuries ; Luminous intensity ; Males ; Mathematical models ; Measuring instruments ; Pavements ; Records management ; Risk management ; Signalized intersections ; Statistics ; Street lighting ; Traffic accidents ; Traffic mitigation ; Trucks ; Visibility ; Weather ; Wet weather

Other Terms Elderly drivers; Exposure; Female drivers; Highway lighting; Male drivers; Mitigation; Prediction; Records; Traffic accident analyses; Wet pavements

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# COMPARISON OF THE SAFETY OF LIGHTING OPTIONS ON URBAN FREEWAYS

*by Michael S. Griffith*



## Introduction

Nationwide accident statistics show that more than 50 percent of fatal accidents occur during the hours of darkness. Because only 25 percent of travel occurs during the same period, the fatality rate is about three times higher at night than during the day. The installation of overhead lighting is a potential countermeasure to this nighttime accident problem. However, this is expensive, and much of the research to date offers inconclusive results about its effect on highway safety.

Many previous studies have evaluated the relationship of urban freeway lighting and highway safety. However, the majority of these studies were conducted in the 1960s and early 1970s, and the results from these studies may be outdated. On our nation's highways, there have been many changes in traffic

flow, vehicle fleet, and road-user demography in the past 20 to 30 years. Clearly, the volume of traffic on urban freeways is significantly higher today, and congestion is a greater problem.

This paper presents the results of a research study that integrated accident, roadway, and traffic volume data from many sources to compare the safety of continuously lighted urban freeways and urban freeways with interchange lighting only. A freeway section with continuous lighting has overhead lighting at the interchanges and between the interchanges, as opposed to overhead lighting at the interchanges only. The urban freeways evaluated in this study are located in the Minneapolis-St. Paul metropolitan area.

The primary data source for the study was the Highway Safety Information System (HSIS). HSIS uses data already collected by five states and annually acquired by the Federal Highway Administration (FHWA). It is a roadway-based system that provides quality data on a large number of accident variables, roadway characteristics, and traffic volumes for problem analyses. An examination of HSIS data files revealed that most of the desired accident and roadway variables to conduct this study were present.

However, none of the files has the complete lighting information or 24-hour traffic distributions needed to develop day versus night accident rates. Lighting information and automatic traffic recorder reports that provide summaries of 24-hour traffic distributions were obtained from Minnesota Department of Transportation (MnDOT). To classify accident and traffic volume data by day and night, sunrise and sunset information was acquired from the United States Naval Observatory.

## Previous Studies

The International Commission on Illumination (CIE) Technical Report *Road Lighting as an Accident Countermeasure* provides a complete and detailed summary of all the studies that have investigated the relationship between urban freeway lighting and safety. (1) The summary includes before-and-after and cross-section studies that examined the safety effectiveness of continuous freeway lighting, interchange lighting, and the impact of reducing lighting levels on urban freeways. The before-and-after approach examines how safety has changed at sites where a treatment or modification was made. The cross-section approach is designed to compare the safety characteristics of two different groups.

In summary, it appears for the limited number of studies that obtained conclusive results, urban freeway lighting has a beneficial effect on safety. However, much of the research is 20 years old or older or was conducted in other countries, and it may not represent the current experience in the United States.

A cross-section study that is considered to be one of the most comprehensive studies of continuous freeway lighting was reported in 1972 by Box. (2) The study included about 320 kilometers (200 miles) of urban freeway on which more than 21,000 accidents occurred during the evaluation period of 1960 to 1968. The studied areas were Denver, Chicago, Atlanta, Dallas, Phoenix, Detroit, and Toronto. Box found that the average night/day accident-rate ratio was 66 percent greater on unlighted freeways than on lighted freeways, and he concluded that the illumination of an unlighted urban freeway could theoretically reduce night accidents by an average of 40 percent.

Three before-and-after studies were conducted in the 1970s. All three studies had fairly small sample sizes. Box evaluated approximately 8 km (5 mi) of a six-lane urban freeway with continuous lighting in Chicago. (2) He concluded that the installation of lighting possibly lowered the night accident rate; however, a complete statistical confirmation is lacking. The results of a French study by Onser showed that night accidents were reduced by 57 percent following installation of lighting on a section of the A1 Motorway. (3) A Japanese study by Nishimori examined a 12.9-km (8-mi) motorway section after overhead lighting was installed and found that the night accident rate was reduced by 56 percent. (4)

There are three studies that examined the impact of the switching off of an existing overhead lighting system on the safety of freeways. One study by Hilton examined the effects of shutting off the lighting system on a 10-lane freeway section located on I-95 in Virginia during the oil embargo period in 1973-74.

The results indicate that switching off the lighting system had a negative impact on safety. The magnitude of the impact was found to vary with the season of the year. (5)

## Approach

A cross-section approach was used in this research study to assess the safety effects of urban freeway lighting. The two groups in this study were urban freeway sections with continuous lighting and urban freeway sections with interchange lighting only. Unfortunately, in this case, there was not an opportunity to conduct a before-and-after study.

In identifying lighted urban freeway sections to be evaluated, only the five states within HSIS were considered. These five states are: Illinois, Maine, Michigan, Minnesota, and Utah. Since Illinois, Michigan, and Minnesota have more and larger metropolitan areas than Maine or Utah, it was decided to investigate the information available from these three states.

Each record on the HSIS roadlog files contains current characteristics of the road system, including shoulder and median information, lane information, surface type and width, etc. However, the roadlog files can't always provide all of the roadway information required for safety analyses.

Minnesota was selected for this study because MnDOT was able to provide the most comprehensive, supplementary information to support HSIS data. MnDOT provided a complete listing of where urban freeway lighting exists within the state and information about the type of lighting at each location. In addition, at the time of this study, Minnesota was the only HSIS state with a videodisc photolog system.

The videodisc photolog system provides additional roadway information that is not contained in the roadway files. Minnesota's videodisc photolog system can be accessed in the HSIS laboratory.

A photolog is a series of sequential images taken from a moving vehicle at approximately driver's eye level to provide a permanent record of the state-maintained roadway network. MnDOT uses an automated vehicle to annually film the entire state highway system in both directions with a videocamera. A photograph is taken every 0.016 km (0.01 mi) with the camera oriented slightly down and to the right for optimum coverage of the highway and roadside development. Video images of the highway are recorded and stored on laser videodiscs.

The videodisc photolog system is a key tool that allows users to have automatic computer access to all video images of the state-maintained roadway network. This system is used to collect supplementary data for studies and to verify existing data.

To enable the development of day versus night accident rates, Minnesota also provided 24-hour traffic distribution information from automatic traffic recorders (ATR), permanent count stations that collect 24-hour traffic data every day of the year.

The accident and traffic volume data were then classified into night and day periods based on sunrise/sunset information for Minneapolis, acquired from the United States Naval Observatory; the time of the accident recorded by the hour in HSIS accident files; and the Minnesota ATR summary reports.

## Site Characteristics

A total of 87.9 km (54.6 mi) of urban freeway segments with continuous lighting and 57.1 km (35.5 mi) of urban freeway segments with interchange lighting only were used in the study. All of the study sections are located in the Minneapolis-St. Paul metropolitan area. A larger sample size (more miles) of urban freeway sections with interchange lighting only would have been useful in this study. Additional sections with interchange lighting only were considered, but they were judged to be inappropriate to include in the study. Information about the characteristics of the study sections were acquired from the HSIS, the Minnesota videodisc photolog system, and from field observations.



**A freeway section with continuous lighting has overhead lighting at the interchanges and between the interchanges.**

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There is one major roadway difference between the urban freeway sections with continuous lighting and those with interchange lighting only. This difference pertains to the number of interchanges per mile. There are 1.2 interchanges per 1.6 km (1 mi) on the continuously lighted sections and 0.8 interchanges per 1.6 km (1 mi) on the sections with interchange lighting only. All of the interchanges are of the diamond type except three that are cloverleaves.

Interchange areas include the areas along the freeway mainline between and including acceleration lanes, deceleration lanes, and their respective ramps. (6) The accident experience in interchange and non-interchange areas is very different, and therefore, the location of interchange/non-interchange areas was considered important information to collect.

Using the videodisc photolog system, interchange areas and non-interchange areas were identified by beginning and ending mileposts for the study sections. About 59 percent of the total miles of continuously lighted sections were identified to be within interchange areas, and only 46 percent of the total miles of sections with interchange lighting only were within interchange areas.

In the field, each study section was examined during nighttime and daytime hours. Driving the sections during the day provided additional information about the roadway and operational characteristics. During night inspections, approximately 10 percent of the lights were observed to be off on the study sections. The lights were most likely off due to the malfunctioning of the system hardware and burned-out lamps. (7)

All of the continuously lighted sections had complete lighting at the interchanges. Complete interchange lighting is used to describe the process of applying lighting to the interchange in such a manner as to achieve illumination of all roadways in the interchanges. (8) Generally, complete interchange lighting is associated with freeways where the main lanes are lighted.

Partial interchange lighting only includes illumination of the parts of the interchange that are considered most critical. The parts most frequently lighted are the merge-diverge areas of the ramp connections, intersections, and critical roadway features.

With one exception, complete or partial lighting existed at the interchanges on the study sections with interchange lighting only. Partial lighting was the "rule" at these interchanges. One of the interchanges on the sections with interchange lighting only had high-mast lighting with the light sources mounted at 30.5 m (100 ft). High-mast lighting provides an uniform distribution of light over the entire area of an interchange. The lighting systems for the study sections have a combination of 200/400-watt, high-pressure sodium luminaires and 400-watt, mercury vapor luminaires. The majority of the luminaires are high-pressure sodium. The pole heights of the luminaires are 9.1 m (30 ft), 12.2 m (40 ft), and 15.2 m (50 ft).

The travel characteristics between the study sections were compared. The day/night distribution of the total vehicle miles traveled (VMT) for the continuously lighted sections and the sections with interchange lighting only was found to be identical. About 76 percent of the total travel occurred during day hours and 24 percent occurred during night hours. The traffic volumes for the freeway sections with continuous lighting and the freeway sections with interchange lighting only are virtually identical (within 5 percent). The average number of vehicles counted per year was 25.8 million for the sections with interchange lighting only and 27 million for the continuously lighted sections.

## Results

Day and night accident rates were calculated for the study sections. Accident data from 1985-1990 was used. Accident rates corresponding to all accidents, serious injury accidents, injury accidents, property-damage-only accidents, interchange area accidents, and non-interchange area accidents were calculated.

Table 1 shows the total day accident rates, total night accident rates, and the total night/day accident-rate ratios. The total day accident rate for continuously lighted sections is three times higher than the total day accident rate for sections with interchange lighting only. This result appears to be reasonable given that there are more interchanges per mile on the freeway sections with continuous lighting than on the sections with interchange lighting only. The accident experience tends to be higher in interchange areas than in non-interchange areas. The total night accident rate for continuously lighted sections is also close to being three times higher than the total night accident rate for sections with interchange lighting only.

**Table 1 - Accident Rates**

	<b>Continuous Lighting</b>	<b>Interchange Lighting</b>	<b>Difference</b>
Total Day Accident Rate	1.50	0.48	
Total Night Accident Rate	1.95	0.70	
Total Night/Day Accident-Rate Ratio	1.30	1.46	+12%*

\*Indicates that the **ratios** are statistically different.

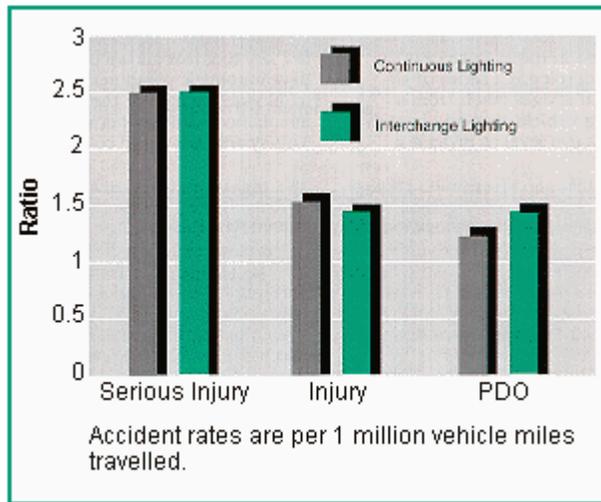
Accident rate is per 1 million vehicle miles (1.6 million kilometers) travelled.

To adjust for the differences between the freeway sections with continuous lighting and those with interchange lighting only, total night/day accident-rate ratios were calculated. The ratio is computed by dividing the total night accident rate by the total day accident rate. The total night/day accident-rate ratio for the sections with interchange lighting only is 12 percent higher than the total night/day accident-rate ratio for sections with continuous lighting (a larger night/day accident-rate ratio indicates a correspondingly more hazardous night condition). The validity of this result is dependent on the assumption that any significant changes (weather, vehicle fleet, road-user demography, etc.) that occurred over the study period, happened in the same manner at both the continuously lighted sections and sections with interchange lighting only. Since the study sections are adjacent to one another, this assumption is reasonable.

The null hypothesis that the total night/day accident-rate ratio for the sections with interchange lighting only is the same as the total night/day accident-rate ratio for the continuously lighted sections was evaluated with a Poisson statistical test at a level of significance equal to 0.05 and was rejected. So, from a statistical perspective, the total night/day accident-rate ratio for the sections with interchange lighting only is greater than the total night/day accident-rate ratio for the continuously lighted sections.

Figure 1 shows serious injury, injury, and PDO night/day accident-rate ratios. The only meaningful difference between the ratios is that the PDO night/day accident-rate ratio is 19 percent higher for the

freeway sections with interchange lighting only than the PDO night/day accident-rate ratio for the continuously lighted sections.

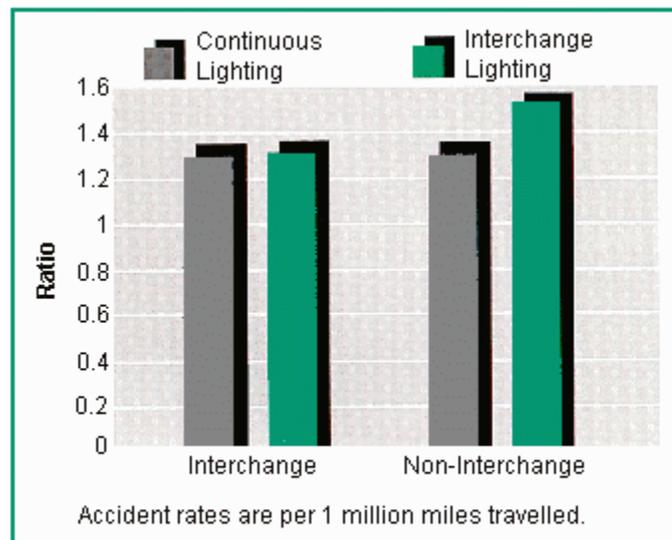


**Figure 1 - Night/day rate ratios.**

Statistical models were fitted to the data to determine which roadway variables (number of lanes, recovery zone [median width + sum of left shoulder widths from both sides of the roadway], median type, and interchange/non-interchange area) are important in predicting accident rates. The best model obtained contains only one independent variable. This variable defines whether a roadway section is in an interchange area or a non-interchange area.

Figure 2 shows the accident-rate ratios for interchange and non-interchange areas.

For interchange areas, the night/day accident-rate ratios are statistically equal for continuously lighted sections and sections with interchange lighting only. One would expect these ratios to be similar since overhead lighting exists at the interchanges located on the sections with continuous lighting and the sections with interchange lighting only.



**Figure 2 - Total night/day rate ratios.**

The night/day accident-rate ratio for non-interchange areas is 18 percent higher for sections with interchange lighting only than it is for continuously lighted sections. Statistically, the night/day accident-rate ratios for non-interchange areas are different. This result is based on a comparison of freeway sections between interchange areas that have overhead lighting to those without overhead lighting. Since it is of particular interest to compare freeway sections with and without overhead lighting, a more detailed analysis of the non-interchange sections was conducted.

Table 2 shows the non-interchange night/day accident-rate ratios for serious injury accidents, total injury accidents, and PDO accidents. The only meaningful difference between the ratios for the lighted sections and the unlighted sections is the one associated with PDO accidents. The PDO night/day accident-rate ratio for freeway sections between interchange areas without lighting is 32 percent higher than the PDO night/day accident-rate ratio for freeway sections with lighting between interchange areas. The differences in serious injury and total injury accident-rate ratios between the roadway sections with lighting and without lighting are statistically insignificant. The 29-percent difference in the serious injury accident-rate ratio between the unlighted and lighted sections is fairly large; however, the small sample size of serious injury accidents prevented this finding from being declared statistically significant using a Poisson statistical test.

**Table 2 - Non-Interchange Night/Day Accident-Rate Ratios**

	<b>Lighting</b>	<b>No Lighting</b>	<b>Difference</b>
Serious Injury Accident-Rate Ratio	4.00	2.86	-29%
Total Injury Accident-Rate Ratio	1.45	1.38	-5%
PDO Accident-Rate Ratio	1.21	1.60	+32%*

\*Indicates that the ratios are statistically different.

Accident rate is per 1 million vehicle miles (1.6 million kilometers) travelled.

A finding of this study and other traffic volume studies is that on average 25 percent of urban freeway traffic consistently occurs at night. This is an important finding for it allows the calculation of rate ratios in the absence of traffic counts. From the literature, it was found that the night/day accident-rate ratio is mathematically equal to three times the number of night accidents divided by the number of day accidents. (2)

This mathematical relationship was examined using the study data and was found to be fairly reasonable. For the lighted sections in non-interchange areas, three times the number of night accidents divided by the number of day accidents equals 1.28, which is practically equal to the computed night/day accident-rate ratio of 1.30. For the unlighted sections in non-interchange areas, the estimated rate of 1.47 is not much different than the computed night/day accident-rate ratio of 1.54. For the continuously lighted sections in interchange areas, the estimated rate of 1.33 is practically equal to the computed night/day accident-rate ratio of 1.30. For the sections with interchange lighting only in interchange areas, the estimated rate of 1.38 is not much different than the computed night/day accident-rate ratio of 1.33.

Given that the mathematical equation was found to be reasonable with data from this study, an analysis was conducted using a derivation of the equation to compute and compare the expected number of night accidents for the lighted and unlighted study sections in non-interchange areas. The expected number of night accidents can be calculated for any assumed night/day accident-rate ratio. Assume a freeway experiences 1,000 day accidents during a time period. For non-interchange areas, the lighted ratio of 1.30 from the study data produces 433 night accidents by use of the equation  $E_N = R * (A_D/3)$ , where  $E_N$  = expected number of night accidents,  $R$  = night/day accident-rate ratio, and  $A_D$  = number of day accidents. (2) The unlighted ratio for non-interchange areas equal to 1.54 from the study data produces 513 night accidents. The difference of the expected number of night accidents between the lighted and unlighted sections is 80 (513 - 433), which represents 16 percent fewer night accidents under lighted conditions. If compared with 1,513 (1,000 + 513) total day and night accidents, the overall reduction would be 5

percent. This example indicates that the illumination of an unlighted urban freeway between interchange areas could theoretically reduce night accidents by 16 percent or total accidents by 5 percent.

Table 3 shows the crash costs for lighted sections between interchange areas classified by night and day. The costs are calculated for each accident severity by multiplying the accident frequency by the corresponding standard cost per crash. The total night and day crash costs are \$37,617,605 and \$46,270,320, respectively.

**Table 3 -- Crash Costs for Lighted Sections between Interchange Areas**

<b>Severity</b>	<b>Cost per Crash</b>	<b>Night Accident Counts</b>	<b>Night Accident Costs</b>	<b>Day Accident Counts</b>	<b>Day Accident Costs</b>
K - Fatal	\$2,722,548	7	\$19,057,836	4	\$10,890,192
A - Incapacitating	228,568	22	5,028,496	28	6,399,904
B - Evident	48,333	118	5,703,294	207	10,004,931
C - Possible	25,228	161	4,061,708	384	9,687,552
0 - Property Damage	4,489	839	3,766,271	2069	9,287,741
<b>Total</b>		<b>1147</b>	<b>\$37,617,605</b>	<b>2692</b>	<b>\$46,270,320</b>

Note: The crash costs are in 1988 dollars. Source: The Costs of Highway Crashes, FHWA-RD-91-055.

Table 4 shows the crash costs for unlighted sections between interchange areas. The total night and day crash costs are \$17,727,099 and \$17,228,489, respectively. The crash-cost values shown in tables 3 and 4 are in 1988 dollars.

**Table 4 -- Crash Costs for Unlighted Sections between Interchange Areas**

<b>Severity</b>	<b>Cost per Crash</b>	<b>Night Accident Counts</b>	<b>Night Accident Costs</b>	<b>Day Accident Counts</b>	<b>Day Accident Costs</b>
K - Fatal	\$2,722,548	5	\$13,612,740	3	\$8,167,644
A - Incapacitating	228,568	6	1,371,408	10	2,285,680
B - Evident	48,333	20	966,660	58	2,803,314
C - Possible	25,228	35	882,980	90	2,270,520
0 - Property Damage	4,489	199	893,311	379	1,701,331
<b>Total</b>		<b>265</b>	<b>\$17,727,099</b>	<b>540</b>	<b>\$17,228,489</b>

Note: The crash costs are in 1988 dollars. Source: The Costs of Highway Crashes, FHWA-RD-91-055.

Night/day crash-cost ratios were computed using the crash costs from tables 3 and 4. The night/day crash-cost ratios for freeway sections between interchange areas with lighting and without lighting are  $\$37,617,605/\$46,270,320 = 0.81$  and  $\$17,727,099/\$17,228,489 = 1.03$ , respectively. The night/day crash-cost ratio for freeway sections between interchange areas without overhead lighting is 27 percent higher

than the night/day crash-cost ratio for freeway sections between interchange areas with overhead lighting.

A benefit/cost analysis was conducted for the freeway sections between the interchange areas with and without lighting. The cost to install and provide electrical power for an urban freeway lighting system was obtained from a New York Department of Transportation (NYDOT) official. The NYDOT official could not provide maintenance costs. Based on the NYDOT cost information, it is estimated that the installation and power costs (in 1988 dollars) for the 35 km (22 mi) of continuously lighted freeways between the interchange areas is \$4,528,560. The overhead lighting on the study sections was installed between 1960 and 1984.

For the benefit/cost analysis, the expected night crash costs (if roadway lighting did not exist at these locations) had to be calculated for the 35 km (22 mi) of continuously lighted freeways between the interchange areas. This was found by using the night/day crash-cost ratio for the unlighted sections between the interchange areas. One would expect if roadway lighting was not installed on the 35 km (22 mi) of continuously lighted freeways between interchange areas that the night/day crash-cost ratio would equal 1.03 (night/day crash-cost ratio for the unlighted sections) and not 0.81. The expected night crash costs are equal to \$47,658,429 ( $\$46,270,320 \times 1.03$ ).

The actual night crash costs are \$37,617,605; this is \$10,040,824 less than the expected night costs. Therefore, the estimated economic benefit of roadway lighting is \$5,512,264 ( $\$10,040,824 - \$4,528,560$  [estimated installation and power costs]) for the years 1985-1990. This is the amount saved by society. The estimate is conservative -- even if one considers that the costs to maintain the lighting systems have not been included in the calculations -- because the roadway lighting was installed at the study sections between 1960 and 1984 and installation costs are based on 1988 dollars. Therefore, the installation costs are inflated. In addition, the safety benefit of lighting before 1985 has been neglected since study data was obtained only for the years 1985-1990.

## Conclusion

The results of this study and the 1972 cross-section study conducted by Box are different. There are several likely reasons why the results are different. These reasons are: (1) Box compared lighted against unlighted sections, and in this study continuously lighted sections were compared against sections with interchange lighting only. (2) About 25 years have passed between the studies. (3) Data from several cities were used in the Box study, and data from only one metropolitan area was used in this study.

Box found that the average night/day accident-rate ratio was 60 percent higher on unlighted freeways (no overhead lighting at the interchanges or between the interchanges) than on lighted freeways. Using accident data between 1985 and 1990, this study found that the total night/day accident-rate ratio for the sections with interchange lighting only is 12 percent higher than the total night/day accident-rate ratio for sections with continuous lighting. In the non-interchange areas, the night/day accident-rate ratio is 18 percent higher for sections with interchange lighting only than it is for continuously lighted sections. Box did not report separate ratios for the non-interchange and interchange areas.

A finding of the Box study indicates that the illumination of an unlighted freeway (installation of overhead lighting at the interchanges and between the interchanges) could theoretically reduce night accidents by an average of 40 percent. This study found that the illumination of an unlighted urban freeway between interchange areas (installation of overhead lighting between the interchanges only) could theoretically reduce night accidents by 16 percent.

Another conclusion of this study is that the relative benefit of overhead lighting for urban freeways between interchange areas is primarily associated with PDO accidents. The PDO night/day accident-rate ratio for unlighted freeway sections between interchange areas is 32 percent higher than the PDO night/day accident-rate ratio for lighted freeway sections between interchange areas. This difference is reflected in the cost analysis that found that the night/day crash-cost ratio for freeway sections between

interchange areas without overhead lighting is 27 percent higher than the night/day crash-cost ratio for freeway sections between interchange areas with overhead lighting.

Jurisdictions considering the installation of a roadway lighting system for an urban freeway facility need to assess its potential economic impact. Benefit/cost analyses should be conducted for different types of freeway lighting systems. The estimated economic benefit of continuous lighting for the study's 22 miles of urban freeways between interchange areas is \$5.5 million. This is the most important result of the study. As a minimum, the installation of roadway lighting at interchanges only on urban freeways should be considered by a jurisdiction as an intermediate step between no lighting and continuous lighting.

This study provided new information about urban freeway accidents and illumination and found a positive relationship between urban freeway lighting and highway safety. Additional research is needed to develop an even stronger knowledge base on urban freeway lighting. It would be desirable to conduct a before-and-after study with data from several states that have urban freeway lighting systems in service with a wide range of maintained illumination levels. MnDOT maintains an average horizontal illuminance in the range of 0.6 to 0.8 footcandle (6 to 9 lux) for their urban freeway lighting system, which meets the American Association of State and Highway Transportation Officials (AASHTO) recommendations. It is not known whether higher illumination levels would result in accident-reduction benefits.

## References

- (1) *Road Lighting as an Accident Countermeasure*, The International Commission on Illumination (CIE) Technical Report, First Edition, 1992.
- (2) P.C. Box. "Freeway Accidents and Illumination," Highway Research Record 416, Highway Research Board, 1972.
- (3) Onser. "Effect of Lighting on Motorways," National Organisation for Road Safety, 1973.
- (4) S. Nishimori. "Effects of the Installation of Lighting on the Whole Length of the Motorway Upon Night Time Accidents," Japan Highway Public Corporation, paper presented at 11th Annual Conference of Japan Road Association, Tokyo, 1973.
- (5) M.H. Hilton. "The Effectiveness of Freeway Lighting in Reducing Accidents," Compendium of Technical Papers ITE 49th Annual Meeting, Institute of Transportation Engineers, Toronto, Canada, 1979.
- (6) J. Twomey, M. Heckman, and J. Hayward. *Safety Effectiveness of Highway Design Features, Volume IV: Interchanges*, Publication No. FHWA-RD-91-047, Federal Highway Administration, Washington, D.C., November 1992.
- (7) "Maintenance Process Review of Highway Lighting," Federal Highway Administration, Minnesota Division, September 1988.
- (8) *Roadway Lighting Handbook*, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., December 1978.

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Title TRADE-OFF BETWEEN DELINEATION AND LIGHTING OF FREEWAY INTERCHANGES: INVESTIGATION OF TRANSIENT VISUAL ADAPTATION

Accession No 00642450

Authors Hostetter, R S; Carter, R G; Dauber, G W

Corp. Authors

/ Publisher IFR Applications, Incorporated ; Federal Highway Administration

Publication Date 19931100

Description 30 p.

Languages English

Abstract The objective was to determine the extent that transient visual adaptation (TVA) affects drivers' detection of targets along partially lighted freeway interchanges. The study expanded a preliminary task on TVA described in publication FHWA-RD-88-223. Twenty-five subjects drove 10 trials on an entrance and an exit ramp. Lighting was manipulated to provide trials in darkness, and with one, two, three, and four luminaires lighted along each ramp. The same drivers returned for a second session of 10 trials, when refractors were replaced with sharp cut-off luminaires (low glare). The drivers pressed a button on a hand-held switch when they detected the 7-in. by 7-in. (17.8-cm by 17.8-cm) gray targets placed on the shoulder at 350 ft (106.75 m) or 475 ft (144.88 m) downstream of the final ramp luminaire. The vehicle computer recorded distances between subjects and targets at the instant of detection.

TRT Terms Dark adaptation ; Drivers ; Freeways ; Glare ; Human subject testing ; Interchanges ; Lighting ; Tracking systems

Other Terms Drivers (Vehicle); Low glare lighting; Target detection; Transient visual adaptation

Subject Areas I83 Accidents and the human factor; H21 FACILITIES DESIGN; H52 HUMAN FACTORS; I85 Road safety devices

Report Number FHWA/RD-91/041

Availability National Technical Information Service

Order Number: PB94-118429/WTS

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Title TRADE-OFF BETWEEN DELINEATION AND LIGHTING ON FREEWAY INTERCHANGES. FINAL REPORT

Accession No 00489985

Authors Hostetter, R S; Crowley, K W; Dauber, G W; Seguin, E L

Period Covered 860100-8906

Corp. Authors

/ Publisher IFR Applications, Incorporated ; Federal Highway Administration

Publication Date 19890800

Description 107 p.; Appendices(3); Figures(38); Photos(2); References(10); Tables(41)

Abstract The objective was to determine whether, with improved delineation, performance at partially lighted interchanges can approach performance under full lighting, particularly in rain. Two field studies were conducted. The first was to determine whether transient visual adaptation

(TVA) influences detection on partially lighted interchanges and could interact with lighting. It was shown that TVA occurs under partial lighting and influences detection up to 600 feet from the last luminaire. The second field study was to determine the effect of lighting, weather, and improved delineation on driver performance. Data were obtained on two exits in dry and wet weather under full lighting with baseline delineation. Data were then obtained under partial lighting, with baseline and three improved delineation systems. Partial lighting at one exit was with one luminaire, at the other with three luminaires. Findings support the contention that full lighting is superior to partial lighting in ramp speed-related measures. Analysis of delineation effects on ramp and spot speeds and on speed distributions showed few differences under dry conditions. In rain, effects were stronger but were neither large enough nor consistent enough to recommend improved delineation over the baseline system. Nonstatistical comparison of the results from the two sites provided evidence that three-luminaire partial lighting was superior to single-luminaire. Performance on ramp segments downstream of the last luminaire suggested TVA influenced results.

TRT Terms Dark adaptation ; Drivers ; Dryness ; Field studies ; Freeways ; Highway delineators ; Interchanges ; Lighting ; Luminaires ; Luminous intensity ; Moisture content ; Personnel performance ; Rain ; Ramps (Interchanges) ; Road markings ; Speed distribution ; Street lighting  
Other Terms Delineators (Traffic); Driver performance; Dry conditions; Freeway entrances and exits; Freeway lighting; Partial lighting; Rainstorm; Traffic marking; Transient visual adaptation; Wet conditions

Subject Areas H21 FACILITIES DESIGN; H52 HUMAN FACTORS; H54 OPERATIONS AND TRAFFIC CONTROL; I85 Road safety devices; H51 SAFETY; I73 Traffic control  
Contract Number DTFH61-85-C-00137  
Report Number FHWA-RD-88-223; NCP-3A2C0012

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Title VISIBILITY FOR HIGHWAY GUIDANCE AND HAZARD DETECTION

Accession No 00623530

Journal Title Transportation Research Record No. 1149

Corp. Authors

/ Publisher Transportation Research Board

Publication Date 19870000

Description 76 p.; Figures; Photos; References; Tables

Abstract This Transportation Research Record contains the following papers: **Effect of Alternative Reduced Lighting Techniques on Hazard Detection, M.S. Janoff and L.K. Staplin;** Characterizing Discomfort Glare from Roadway Lighting, C.A. Bennett; Evaluation of Headlamp Systems for Nighttime Safety: Their Relationship to Retroreflective Traffic Sign Performance, R.L. Austin and H.L. Woltman; Marine Visibility Research and Development Initiatives of the U.S. Coast Guard, D. Henderson and B. May; Legibility of Freeway Guide Signs as Determined by Sign Materials, R.W. McNeese and H.D. Jones; Contrast Sensitivity, Drivers' Visibility, and Vision Standards, A.P. Ginsburg; Effect of Alternate Population Mixes on Design Eye Locations in Vehicles, A.J. Arnold, R.A. Ferrara, and T.J. Kuechenmeister; Measuring Wet-Night Delineation Reflectivity, R. Dejaiffe; Use of Reflectorization to Reduce Truck-Trailer Accidents, W.J. Burger and R.L. Smith; Driver Lateral Control Performance as a

Function of Delineation, H.T. Zwahlen; and Establishing a Minimum Functional Reflectance for Raised Pavement Markers, R.W. McNees.

TRT Terms Contrast ; Detectors ; Drivers ; Eye location ; Glare ; Guide signs ; Hazards ; Headlamps ; Legibility ; Materials ; Moisture content ; Night ; Performance ; Raised road markings ; Reflectivity ; Reflectorized materials ; Reflectorized road markings ; Retroreflectivity ; Safety ; Spacing ; Street lighting ; Tractor trailer combinations ; Traffic signs ; Vehicle design ; Visibility ; Vision

Other Terms Accident reduction; Contrast sensitivity; Detection; Driver vision; Eye height; Headlights; Highway lighting; Lateral position; Raised reflectorized traffic markers; Reflectorization; Tractor trailers; Traffic sign legibility; Traffic sign materials; Wet conditions  
ISBN 0-309-04659-9

Report Number HS-041 260

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Title FREEWAY LIGHTING AND TRAFFIC SAFETY - A LONG-TERM INVESTIGATION

Accession No 00457436

Authors Lamm, R; Kloeckner, J H; Choueiri, E M

Journal Title Transportation Research Record No. 1027

Corp. Authors

/ Publisher Transportation Research Board

Publication Date 19850000

Description p. 57-63; Figures(2); References(10); Tables(4)

Abstract The objective of this study was to assess the effectiveness of freeway lighting. To achieve this, a case study on traffic accident characteristics was conducted that utilized a suburban freeway area west of Frankfurt, Federal Republic of Germany, between 1972 and 1981. The study revealed that (a) the effects of lighting on suburban freeway accident rates was positive -- there was a reduction in accidents, and (b) these positive results of continuous freeway lighting were lost in the case of partial lighting, especially after switching off lights at night between 10:00 p.m. and 5:30 a.m. for the purpose of saving energy.

Supplemental

Information This paper appeared in Transportation Research Record N1027, Driver Information Needs and Visibility of Traffic Control Devices.

TRT Terms Accident rates ; Case studies ; Freeways ; Reduction (Chemistry) ; Street lighting ; Traffic safety

Other Terms Freeway lighting; Reduction

Subject Areas H52 HUMAN FACTORS; H54 OPERATIONS AND TRAFFIC CONTROL; H51 SAFETY; I72 Traffic and transport planning

Report Number HS-040 075

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Title REDUCED FREEWAY LIGHTING

Accession No 00450845

Authors Janoff, M S; Zlotnick, N L

Journal Title Lighting Design and Application Vol. 15 No. 8

Corp. Authors

/ Publisher Illuminating Engineering Society

Publication Date 19850800

Description p. 35-42; References(7)

Abstract The paper discusses various systems that have been employed to reduce roadway lighting, their costs, benefits, and potential legal problems that must be addressed. Two general types of systems were identified: 1) older and oil-embargo related systems, such as extinguishing the lighting on all or part of specified roadways during various time periods and 2) modern systems that are controlled by special ballasts, electronic sensors and controls, and computers. It is concluded that under both the common law and state Tort Claims Acts, the specter of liability is present for a municipal entity which seeks to reduce or eliminate lighting on its highways during periods of low traffic density. Any municipal agency which undertakes such a program will be well advised to do so only after extensive scientific research and study.

TRT Terms Cost accounting ; Energy conservation ; Freeways ; Highway engineering ; Illuminating engineering ; Legal factors ; Legislation ; Liability ; Lighting systems ; Reduction (Chemistry) ; Street lighting

Other Terms Electric lighting; Freeway lighting; Legal aspect; Legal implications; Outdoor; Reduced freeway lighting; Reduction

Subject Areas H21 FACILITIES DESIGN; I85 Road safety devices; H51 SAFETY

Availability Linda Hall Library

Document Source Engineering Index

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Title REDUCED LIGHTING ON FREEWAYS DURING PERIODS OF LOW TRAFFIC DENSITY. FINAL REPORT

Accession No 00457010

Authors Staplin, L K; Janoff, M S; Decina, L E

Corp. Authors

/ Publisher Ketron, Incorporated ; Federal Highway Administration

Publication Date 19850800

Description 56 p.

Abstract The primary objective of this study was to determine if freeway lighting can be reduced or eliminated during nighttime periods when traffic volume is much lower than design capacity without causing significant reductions in the ability of drivers to control their vehicles in a safe and effective manner. This objective was met by the performance of ten tasks that included a review of the literature and state and foreign experiences; development of a conceptual model of visibility needs; identification of alternative light reduction tactics--including all (luminaires) off, every other off, one side off, and different types and levels of dimming; determination of the costs, potential energy savings, and potential legal implications of such light reduction tactics; and, finally, determination of the effect of such tactics on driver detection of simulated roadway hazards under actual traffic conditions. The major conclusions of this research are that present technology exists for implementing all of the identified tactics, with benefit-to-cost ratios greater than 1.0 for all but the most complex tactics; decrements in driver detection performance were

measured under each reduced lighting tactic in comparison to performance under full lighting, minimally so for dimmed and every other configurations and significantly so for one sided and all off configurations; and, a potential for legal problems may result with the use of reduced lighting tactics. The recommendations arising from this research include the preferred use of fixed dimming circuits, primarily for new systems, with an inexpensive alternative being the extinguishment of every other luminaire for either new or existing systems.

TRT Terms Benefit cost analysis ; Drivers ; Freeways ; Legal factors ; Personnel performance ; Reduction (Chemistry) ; Street lighting ; Traffic safety

Other Terms Driver performance; Freeway lighting; Legal aspect; Reduction

Subject Areas H21 FACILITIES DESIGN; H54 OPERATIONS AND TRAFFIC CONTROL;

I85 Road safety devices; H51 SAFETY

Contract Number DTFH61-83-C-00056

Report Number FHWA/RD-86/018 8308-8508; 3222; FCP 31P3-042

Availability National Technical Information Service

Order Number: PB86-203890/XAB

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Title COSTS, BENEFITS, AND LEGAL IMPLICATIONS OF REDUCED FREEWAY LIGHTING

Accession No 00390398

Authors Janoff, M S; Staplin, L K

Journal Title APWA Reporter Vol. 51 No. 10

Corp. Authors

/ Publisher American Public Works Association ; American Public Works Association

Publication Date 19841000

Description p. 16-17

Abstract A group of lighting experts were asked to rate various reduced lighting systems with respect to potential effects on energy use, safety, other traffic operations, practicality, cost, and legal problems. Both older, oil-embargo related systems, such as turning off the lights on all or part of specified roadways during various time periods, and modern systems controlled by special ballasts, electronic sensors and controls, and computers were studied. The simplest (all off) tactic and dimming 50 percent after midnight scored highest, followed by two luminaires per pole, one side of, variable level lighting as a function of traffic volume, and every other light out after midnight. The simplest systems had very high benefit/cost ratios, while the more sophisticated systems scored higher in safety results and legal implications. A review of court cases and the legal literature indicate that municipal agencies would be liable for damages incurred as a result of reduced lighting. It is therefore imperative that the decision to reduce lighting be based on sound scientific information encompassing every foreseeable contingency.

TRT Terms Cost effectiveness ; Energy conservation ; Liability ; Reduction (Chemistry) ; Street lighting ; Traffic safety

Other Terms Highway lighting; Methods; Reduction

Subject Areas H70 LAW; H54 OPERATIONS AND TRAFFIC CONTROL; I85 Road safety devices; H51 SAFETY

Availability American Public Works Association

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Title EFFECTS OF PARTIAL LIGHTING ON TRAFFIC OPERATIONS AT FREEWAY INTERCHANGES

Accession No 00388864

Authors Janoff, M S

Journal Title Lighting Design and Application Vol. 14 No. 5

Corp. Authors

/ Publisher Illuminating Engineering Society

Publication Date 19840500

Description p. 46

Abstract The objective of this research was to determine the effectiveness of partial lighting of interchanges in comparison to complete interchange lighting and no lighting and to develop recommendations for its use. Two interchanges with modern geometric design and modern complete interchange lighting (CIL) systems were identified. Permission was obtained from the highway lighting authorities to temporarily modify each lighting system so that various levels of partial interchange lighting (PIL) and no lighting conditions could be provided. The paper is organized into five parts: experimental design, which includes site selection, definition of independent variables and selection of dependent measures; design and development of the data collection system; installation of equipment and data collection; data analysis and results; and interpretation and conclusions.

TRT Terms Freeways ; Highway operations ; Highways ; Impact studies ; Interchanges ; Lighting ; Lighting systems ; Street lighting ; Traffic ; Traffic accidents ; Traffic surveys

Geographical Terms United States

Other Terms Electric lighting; Freeway lighting; Highway accidents; Highway systems; Outdoor; Partial lighting; Traffic operations

Subject Areas H21 FACILITIES DESIGN; I85 Road safety devices; H51 SAFETY

Availability Linda Hall Library

Document Source Engineering Index

Source Data: EIX840700067

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Title EFFECTS OF PARTIAL LIGHTING ON TRAFFIC OPERATIONS AT A FREEWAY INTERCHANGE

Accession No 00378865

Authors Janoff, M S; Freedman, M

Journal Title Transportation Research Record No. 904

Corp. Authors

/ Publisher Transportation Research Board

Publication Date 19830000

Description p. 92-96; Figures(2); References(1); Tables(2)

Abstract The objective of this paper is to report the results of an experiment that evaluated the effects of partial interchange lighting, complete interchange lighting, and no lighting on traffic operations at a freeway interchange. A freeway interchange that possessed a modern and complete lighting system was chosen for the experiment. The lighting was temporarily modified

so that two levels of partial lighting and unlit conditions could be provided. Traffic operational data that consisted of velocities, accelerations, brake occurrences, gore and shoulder encroachments, high-beam use, and diverging and merging patterns were collected for five study conditions--daylight, complete lighting, partial lighting (two types), and no lighting--for both an exit and an entrance ramp by using a newly designed data-collection system capable of recording complete trajectory information on individual vehicles. The results indicated that complete interchange lighting is superior to partial interchange lighting in providing smoother and safer nighttime operations at the interchange.

#### Supplemental

Information This paper appeared in Transportation Research Record No. 904, Highway Information Systems, Visibility, and Pedestrian Safety.

TRT Terms Freeways ; Highway operations ; Highway safety ; Impact studies ; Interchanges ; Lighting ; Night ; Street lighting ; Traffic

Other Terms Freeway lighting; Partial lighting; Traffic operations

Subject Areas H54 OPERATIONS AND TRAFFIC CONTROL; I85 Road safety devices; H51 SAFETY

Report Number HS-036 176

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Title PARTIAL LIGHTING OF INTERCHANGES

Accession No 00371694

Authors Janoff, M S; Freedman, M; Decina, L E

Journal Title NCHRP Report No. 256

Corp. Authors

/ Publisher Transportation Research Board

Publication Date 19821200

Description 81 p.; Figures; References; Tables

Abstract This study was designed to determine the effectiveness of partial lighting (lighting that consists of a few luminaires located in the general areas where entrance and exit ramps connect with the through traffic lanes of the freeway) of interchanges and to develop recommendations for its use. This study concentrated on the benefits of lighting rather than on the costs, and crossroad lighting at the ramp terminals was not included. The study included a literature review, a questionnaire survey and analyses to isolate reasons for selecting or rejecting specific types of lighting and interchange designs, the variation of lighting warrants, and the availability of accident and traffic operational data and the results of analyses of the effectiveness of interchange lighting and traffic operations. The study found that 37% of the interchange lighting is complete interchange lighting (CIL) and 63% is partial interchange lighting (PIL). The study concluded that (1) CIL performs better than PIL to systems consisting of 1, 2, or 4 luminaires; (2) either CIL or PIL performs better than no lighting; (3) PILs with fewer luminaires one or two perform better than PILs with more luminaires (four); (4) there is a tradeoff between cost and traffic operations and safety factors in the design of freeway interchange lighting; and (5) existing CIL systems should not be reduced to PIL systems if traffic operations and safety (defined in terms of driver behavior measures) are important considerations.

TRT Terms Highway design ; Highway operations ; Interchanges ; Lighting ; Measures of effectiveness ; Reduction (Chemistry) ; Street lighting ; Traffic ; Traffic safety

Other Terms Effectiveness; Highway lighting; Interchange design; Partial lighting; Reduction;  
Traffic operations  
Subject Areas I82 Accidents and the road; H52 HUMAN FACTORS; H54 OPERATIONS AND  
TRAFFIC CONTROL; H51 SAFETY  
Report Number HS-035 194

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Title EFFECTS OF TURNING OFF SELECTED ROADWAY LIGHTING AS AN ENERGY  
CONSERVATION MEASURE

Accession No 00345318

Authors Richards, S H

Journal Title Transportation Research Record No. 811

Corp. Authors

/ Publisher Transportation Research Board

Publication Date 19810000

Description p. 23-25; References(3); Tables(2)

Abstract In early 1973, the continuous roadway lighting on the southbound main lanes of Interstate 35 through Austin, Texas, was turned off as a power-saving measure in response to a critical area energy shortage. Analyses of accident data revealed that this cutback in roadway lighting significantly increased the frequency, rate, and severity of nighttime accidents in the affected freeway sections. The most notable increases were associated with a sharp rise in nighttime rear-end and pedestrian-related accidents. The cutback in roadway lighting saved approximately 450000 kW-h of electrical power per year, enough to maintain 20 all-electric homes of average size for the same time period. In terms of energy cost savings to the city, this reduction amounted to \$25,250/year. In addition, estimated savings of \$2500/year in lamp-replacement costs were realized through the cutback. However, increases in accident costs after the lighting cutback were conservatively estimated to be slightly less than \$17,000/year. Therefore, although positive energy conservation gains were made through the lighting cutback, these gains were accompanied by a measurable decrease in motorist safety. (Author)

Supplemental

Information This paper appeared in Transportation Research Record No. 811, Speed Enforcement, Visibility, and Effects of Traffic Control Measures on Drivers.

TRT Terms Accident rates ; Accident severity ; Benefit cost analysis ; Freeways ; Night ;

Pedestrian accidents ; Rear end collisions ; Service agencies ; Street lighting ; Traffic accidents

Other Terms Freeway lighting; Freeway traffic accidents; Highway lighting; Social services

Subject Areas H17 ENERGY AND ENVIRONMENT; I85 Road safety devices; H51 SAFETY

Availability Transportation Research Board Business Office

Order Document: [http://nationalacademies.org/trb/publications/tris/out\\_of\\_print.html](http://nationalacademies.org/trb/publications/tris/out_of_print.html)

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Title ROADWAY LIGHTING SPECIFICATION BASED ON SAFE TRAFFIC NEEDS

Accession No 00179839

Authors Ketvitris, A; Wienstein, W; Cooper, P J

Journal Title World Highways/Routes du Monde

Corp. Authors

/ Publisher INTERNATIONAL ROAD FEDERATION. ; Route One Publishing Limited

Publication Date 19771000

Description p. 155-156

Abstract The new road design manual entitled "Geometric Design Standards for Canadian Roads and Streets" published by the Roads and Transportation Association of Canada (RTAC) features, among other changes, a completed revised section on roadway illumination. These new Canadian lighting standards incorporate both illuminance and luminance methods of calculations and suggest design criteria including luminance and illuminance levels, uniformity and glare control. The design criteria is based mainly on traffic safety needs. However, energy conservation and system operation economics are also discussed. The latter problem is described in terms of light and maintenance procedures. Prior to the establishment of the new standardized methods and the design criteria and extensive investigation of lighting needs for Canadian conditions was carried out. This project was sponsored by Transport Canada and conducted by Fenco Consultants Ltd as the research agency. The lighting quantitative needs in the new Canadian standards were based on detectability of critical-size objects at a safe stopping sight distance. For freeway class roads it was determined that effective visibility conditions can be achieved with luminance levels of 0.8 cd/sq sq m. By recognizing both luminance and illuminance as integral components of lighting system design procedures, it is suggested that such an approach enables the designer to assess more accurately the total illumination potential.

Supplemental

Information This paper was presented at the 8th IRF World Meeting, Tokyo, Japan, October 16-21., 1977. Full text also written in Japanese.

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Title INTERIM GUIDE FOR FREEWAY LIGHTING (METRIC UNITS)

Accession No 00081618

Corp. Authors

/ Publisher National Association of Australian State Road Auth

Publication Date 19740000

Description 18 p.; Figures(2)

Abstract This publication which sets out interim guidelines for the lighting of freeways, is intended to be read in conjunction with the Australian Standard AS 1158, Part 1 - Lighting of Urban Traffic routes. Warrants for freeway lighting are described which may need to be varied in special or unusual cases. A consideration of design criteria covers such aspects as level of luminance, uniformity of luminance, and transition lighting. Types of lighting sources are listed and various aspects of lighting poles are discussed. Practical installation geometrics are reviewed, as well as alternative arrangements for lighting of the through carriageways. Lighting on freeway bridges, freeway underpasses and tunnels are outlined. Typical lighting arrangements are listed, as well as current developments in freeway lighting.

TRT Terms Arterial highways ; Bridges ; Brightness ; Building ; Design ; Facilities ; Freeways ; Geometry ; Guidelines ; Installation ; Light ; Lighting systems ; Poles (Supports) ; Street lighting ; Transition zone (Fluid mechanics) ; Tunnels ; Underpasses

Other Terms Design criteria; Freeway lighting; Installing; Light sources; Pole; Through highway; Transition zones; Tunnel lighting; Warrants  
Subject Areas H51 SAFETY

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Title TRADE-OFF BETWEEN DELINEATION AND LIGHTING OF FREEWAY INTERCHANGES: INVESTIGATION OF TRANSIENT VISUAL ADAPTATION

Accession No 00642450

Authors Hostetter, R S; Carter, R G; Dauber, G W

Corp. Authors

/ Publisher IFR Applications, Incorporated ; Federal Highway Administration

Publication Date 19931100

Description 30 p.

Languages English

Abstract The objective was to determine the extent that transient visual adaptation (TVA) affects drivers' detection of targets along partially lighted freeway interchanges. The study expanded a preliminary task on TVA described in publication FHWA-RD-88-223. Twenty-five subjects drove 10 trials on an entrance and an exit ramp. Lighting was manipulated to provide trials in darkness, and with one, two, three, and four luminaires lighted along each ramp. The same drivers returned for a second session of 10 trials, when refractors were replaced with sharp cut-off luminaires (low glare). The drivers pressed a button on a hand-held switch when they detected the 7-in. by 7-in. (17.8-cm by 17.8-cm) gray targets placed on the shoulder at 350 ft (106.75 m) or 475 ft (144.88 m) downstream of the final ramp luminaire. The vehicle computer recorded distances between subjects and targets at the instant of detection.

TRT Terms Dark adaptation ; Drivers ; Freeways ; Glare ; Human subject testing ; Interchanges ; Lighting ; Tracking systems

Other Terms Drivers (Vehicle); Low glare lighting; Target detection; Transient visual adaptation

Subject Areas I83 Accidents and the human factor; H21 FACILITIES DESIGN; H52 HUMAN FACTORS; I85 Road safety devices

Report Number FHWA/RD-91/041

Availability National Technical Information Service

Order Number: PB94-118429/WTS

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Title VISIBILITY LOSSES CAUSED BY TRANSIENT ADAPTATION AT LOW LUMINANCE LEVELS

Accession No 00129390

Authors Rinalducci, E J; Beare, A N

Journal Title Transportation Research Board Special Report No. 156

Corp. Authors

/ Publisher Transportation Research Board

Publication Date 19750000

Description p. 11-22; Figures(11); References(14)

Abstract Transient adaptation refers to the rapid fluctuations in the sensitivity of the eye that result from sudden changes in luminance level. The research reported here examines the effects of transient adaptation and resultant losses in visibility by using luminance levels comparable to nighttime highway lighting conditions. At low luminance levels, sudden increases produce losses in visibility equivalent to those previously founded at higher levels. However, at low luminance levels, decreases produce smaller losses than those observed at higher luminance levels. The results also suggest that there is a preadapting level or range of levels below which there is little or no difference between visibility losses for 10- and 100-fold decreases and above which there is a difference. The transition appears to be a gradual one and is complete at about 8 ft L. The findings of these investigations suggest that visibility loss depends more on the ratio of steady-state thresholds, particularly at low luminance levels, than on the ratio of luminance change as previously supposed. Research has been initiated on the problem of nonuniformities in roadway luminances in the motorist's visual environment. Results indicate that the size of a nonuniformity may have little effect on transient adaptation. However, experiments to examine multiple nonuniformities and the effect of nonuniformities at various distances from the line of sight on transient adaptation are planned.

Supplemental

Information Presented at a symposium conducted by TRB, September 4-6, 1974 at Ohio State University, and sponsored by TRB, Illuminating Engineering Research Institute, Ohio University and Ohio Department of Transportation.

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Title LOSSES IN NIGHTTIME VISIBILITY CAUSED BY TRANSIENT ADAPTATION

Accession No 00263063

Authors Rinalducci, E J

Journal Title Illuminating Engineering Society, Journal of Vol. 3 No. 4

Corp. Authors

/ Publisher Illuminating Engineering Society

Publication Date 19740700

Description p. 336-345

Abstract Research on transient visual adaptation is concerned with the quick changes in sensitivity which the eye makes as it adjusts to variations in luminance levels. Investigations reported here provide a description of transient adaptation effects at luminance levels comparable to those found in nighttime highway lighting conditions. Findings indicate that for downward changes from a low luminance to an even lower one, smaller losses were observed than those found at higher luminance levels. Visibility loss breaks down at the lower limit of 0.002 to 0.02 fL (0.0069 to 0.069 cd/sq m). Individual differences in the amount of visibility loss for a given luminance change, whether upwards or downwards, were found to be large. Within the limits examined, the size of the target has no effect on the degree of visibility loss as measured by the interval between the beginning of the transition from one background to another and the onset of the test-letter presentation.

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Title A PRESCRIPTION FOR ROAD WAY LIGHTING

Accession No 00222382  
Authors Blackwell, O M  
Journal Title Lighting Design and Application Vol. 4 No. 2  
Corp. Authors  
/ Publisher Illuminating Engineering Society  
Publication Date 19740200

Description p. 38-41; Figures(3); References(6)

Abstract THE RESEARCH REPORTED WAS DIRECTED TOWARD APPLYING THE CIE METHODS (CIE REPORT NO. 19) TO ROADWAY TASKS. AN ASSESSMENT WAS MADE OF THE VISIBILITY OF REALISTIC TARGETS IN DIFFERENT LOCATIONS ON A SIMULATED 8-LANE URBAN FREEWAY ILLUMINATED BY REALISTIC LUMINAIRES AT REALISTIC SPACINGS AND MOUNTING HEIGHTS, AS WELL AS BY A SYSTEM PROVIDING GENERALLY UNIFORM ILLUMINATION. THE RELEVANT INFORMATION CRITERION WAS DEFINED AS THE VISIBILITY OF THE TARGET THAT ENABLED AN OBSERVER TO "JUST BARELY DISCERN SOMETHING ON THE ROADWAY THAT SHOULD BE HEADED." FROM THIS VALUE, THE EQUIVALENT CONTRAST (C) WAS DETERMINED. THE VALUES OF C WERE IN TURN USED TO DETERMINE THE VISIBILITY LEVEL (VL). TO TAKE INTO ACCOUNT THE EFFECTS OF SPATIAL PATTERNS (NONUNIFORMITIES), THE EFFECTIVE VISIBILITY LEVEL (EFVL) HAD TO BE DETERMINED. THE TWO FACTORS INVOLVED IN DETERMINING EFVL WERE THE DISABILITY GLARE FACTOR AND THE TRANSIENT ADAPTATION FACTOR, BOTH DESCRIBED IN DETAIL IN CIE REPORT NO. 19. IT SHOULD BE NOTED THAT EFVL VALUES WERE BASED ON AVERAGED REFERENCE DATA OBTAINED FROM 20 TO 30 YEAR -OLDS. THE EFVL VALUES OBTAINED FOR AN OLDER AGE GROUP WERE HIGHER. FUTURE RESEARCH WILL BE DIRECTED TOWARD STUDYING DIFFERENT ACTUAL VISUAL TASKS ON THE ROADWAY IN TERMS OF EFVL. FOR EXAMPLE, AN INVESTIGATION WILL BE CONDUCTED ON DETECTION DISTANCES FOR A STANDARD MULTIDIMENSIONAL TARGET AT DIFFERENT EFVL.

TRT Terms Glare ; Shape ; Street lighting ; Visibility ; Visual perception

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Title TRANSITIONAL ADAPTATION IN TUNNEL LIGHTING

Accession No 00221784

Authors Rinalducci, E J

Journal Title Highway Research Circular No. 137

Publication Date 19720800

Description p. 1-8; Figures(9); References

Abstract THE PHENOMENON OF TRANSITIONAL ADAPTATION CONCERNS CHANGES IN VISIBILITY RESULTING FROM SUDDEN INCREASES AND DECREASES IN THE PREVAILING LUMINANCE LEVEL OF THE VISUAL FIELD. SUDDEN TRANSITIONS IN TUNNEL LIGHTING ARE ABLE TO PRODUCE A "BLACK-OUT" EFFECT AT THE ENTRANCE OF A TUNNEL, CREATE BLIND SPOTS AT BOTH ENTRANCES AND EXITS, AND REDUCE TRAFFIC SPEED THROUGH THE TUNNEL. IN ADDITION, DISCONTINUOUS OR SPACED LIGHTING FIXTURES WITHIN A TUNNEL MAY PRODUCE A FLICKERING EFFECT THAT CAN ALSO REQUIRE TRANSITIONAL ADAPTATION. WHEN THE EYE IS PRESENTED WITH A SUDDEN

INCREASE OR DECREASE IN THE PREVAILING LEVEL OF ILLUMINATION, A TRANSIENT BURST OF ACTIVITY OCCURS IN THE RETINA WHICH IS TRANSMITTED TO THE BRAIN, SIGNALLING THIS CHANGE. IF THE INDIVIDUAL IS ASKED TO PERFORM A VISUAL TASK AT THIS TIME, A GREATER CONTRAST BETWEEN THE VISUAL STIMULUS AND ITS BACKGROUND WILL BE REQUIRED, BECAUSE THE VISUAL SYSTEM IS BUSY HANDLING INFORMATION RELATED TO THE CHANGE IN LUMINANCE LEVEL. EXPERIMENTS HAVE BEEN CONDUCTED AT THE UNIVERSITY OF ROCHESTER AND THE UNIVERSITY OF VIRGINIA TO SIMULATE THIS PHENOMENON UNDER TYPICAL DRIVING CONDITIONS, SUCH AS DRIVING IN TUNNELS OR AT NIGHT. THE EXPERIMENTS ARE DESCRIBED, AND THEIR RELEVANCE FOR THE DESIGN OF HIGHWAY LIGHTING SYSTEMS IS TREATED BRIEFLY.

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Title ILLUMINATION OF ISOLATED RURAL INTERSECTIONS

Accession No 00811287

Authors Gibbs, M; SHAFLIK, C; ZEIN, S

Corp. Authors

/ Publisher Transportation Association of Canada ; BRITISH COLUMBIA. MINISTRY OF TRANSPORTATION AND HIGHWAYS ; Alberta Transportation

Publication Date 20010200

Description 25 p.

Languages English

Abstract Illumination of isolated Rural Intersections is an update to illumination practices found in 1983 Guide for the Design of Road Lighting published by the Transportation Association of Canada (T Existing and/or proposed lighting warrants and practices of all Canadian provinces, the TAC warrant and three U.S. states are reviewed in order to develop a Canadian warrant illumination of isolated rural intersections. The warrant is based on geometric, operational, environmental and collision factors. The critical factors determining the need for illumination are traffic volumes night-time collisions attributable to lack of lighting and extent raised channelizations. The warrant indicates whether full intersection lighting, partial lighting or delineation lighting is needed. Full intersection lighting denotes illumination covering intersection in a uniform manner over the traveled portion of roadway. Partial lighting is the illumination of key decision or potential conflict points, and/or hazards in and on the approach an intersection. The illumination of vehicles on a cross street median crossing, or lighting that marks an intersection location approaching traffic, is referred to as sentry or delineating lighting. The warrant provides a method for selecting and prioritizing intersection at which lighting will be beneficial and identifies an appropriate lighting system. Layouts for partial a delineation lighting concentrate on illumination of the main traf conflict areas with additional lighting in spot areas for potenti hazard. Also discussed are the safety benefits of lighting at ru intersections and other intersection safety measures. Examples o various applications of the warrant are included.

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Title SAFETY IMPACTS OF STREET LIGHTING AT ISOLATED RURAL INTERSECTIONS

Accession No 00771240

Authors Preston, H; Schoenecker, T

Period Covered 9801-9904

Corp. Authors

/ Publisher BRW, Incorporated ; Minnesota Department of Transportation

Publication Date 19990400

Description 112 p.; Appendices(5); Figures; Tables

Languages English

Abstract This report details the results of a study that examined the effectiveness of installing streetlights at rural intersections. The report concluded that the installation of streetlights at rural intersections offers a low-cost and very effective strategy for mitigating night-time crashes. Previously published reports found that the installation of intersection lighting resulted in a 25 to 50% reduction in the night-time crash/total crash ratio. A survey of Minnesota cities and counties indicated that most agencies do not operate or maintain streetlights at rural intersections and most have no warrants or guidelines for installation of streetlights. The results of both a comparative analysis of more than 3,400 rural intersections along the state's trunk highway system and a before-and-after analysis of a sample of 12 intersections found that the installation of streetlights reduced night-time crashes at rural intersections and would likely be far more effective than either rumble strips or overhead flashing beacons. A benefit-cost analysis indicated that the benefits associated with the installation of street lighting at rural intersections outweigh the costs by a margin of 15 to one.

TRT Terms Accidents ; Before and after studies ; Benefit cost analysis ; Countermeasures ; Intersections ; Rural areas ; Street lighting

Geographical Terms Minnesota

Subject Areas I81 Accident statistics; H21 FACILITIES DESIGN; I21 Highway and transport planning; H51 SAFETY

Contract Number 74326 TOC #1

Report Number MN/RC-1999-17,; Final Report

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Title MAJOR ROAD ACCIDENT REDUCTION BY ILLUMINATION

Accession No 00495502

Authors Box, P C

Journal Title Transportation Research Record No. 1247

Corp. Authors

/ Publisher Transportation Research Board

Publication Date 19890000

Description p. 32-38; Figures(1); Photos(2); References(9); Tables(7)

Abstract This paper presents the accident reduction effect found by installing roadway lighting in conformance with the American National Standard Practice for Roadway Lighting. A portion of Ogden Avenue in Naperville, Illinois, had only one block of modern lighting plus a few intersection lights in a length of 2.8 km. This five-lane roadway (two through lanes plus a center two-way left-turn lane) is 18 m wide. Street lighting was installed and maintained at a design level of 15 Lux, as appropriate for a major route in an intermediate area. A 4-year study of accidents was made, with 1984 and 1985 used in the "before" period and 1986 and 1987 in the "after" period. More than 800 accidents occurred during the total study period. Overall, accidents were reduced from 31% at night to 23% in the "after" period. The greatest reduction was in midblock locations, where the "before" percentage was 35 and the "after" was 21. The night

accident reduction was 36%, calculated either on a night/day ratio of rates per million vehicle kilometers or by the simpler method of night percent change. If total day plus night accidents are considered, the overall accident reduction was 14%. An economic analysis, comparing the installation cost with the estimated cost of accidents prevented, showed payback in one year.

Supplemental

Information This paper appears in Transportation Research Record No. 1247, Visibility Criteria for Signs, Signals, and Roadway Lighting.

TRT Terms Before and after studies ; Cost effectiveness ; Days ; Economic analysis ; Measures of effectiveness ; Night ; Safety ; Street lighting

Other Terms Accident reduction; Effectiveness; Highway lighting

Subject Areas H52 HUMAN FACTORS; I85 Road safety devices; H51 SAFETY

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