# ENGINEERING ECONOMY AND ENERGY CONSIDERATIONS

WARRANTS AND PRIORITIES FOR ROADWAY LIGHTING

RESEARCH REPORT 214-13

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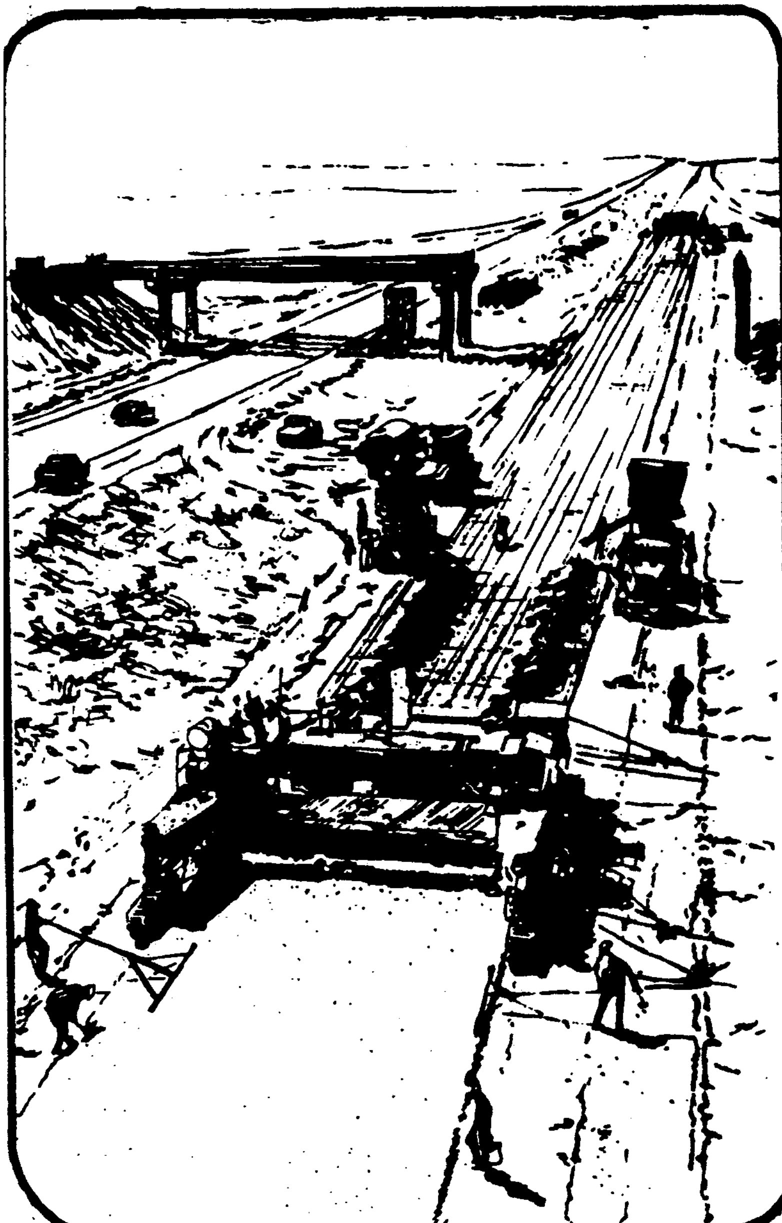

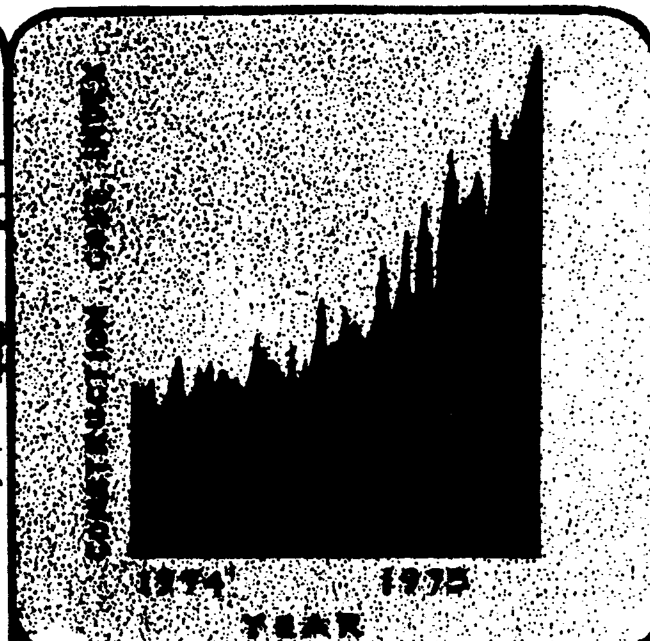

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"ENGINEERING, ECONOMY AND ENERGY CONSIDERATIONS IN DESIGN, CONSTRUCTION AND MATERIALS"

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

AND

TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY

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# WARRANTS AND PRIORITIES FOR ROADWAY LIGHTING

By

Ned E. Walton

## Introduction

The justification for the installation and maintenance costs for an illumination project should be its cost-effectiveness. One way of determining whether lighting is justified is to evaluate the geometric and environmental conditions for a facility by developing a warrant point index. This warrant point index can be used to assist in determining if a new lighting installation is warranted and also can be used as the basis for a priority index. Both uses of the warrant point index are discussed in later sections of this report.

In addition to being used to determine priorities for new facilities, the priority index can be used to rank existing facilities on the basis of effectiveness and cost. However, initial costs of existing installations are "sunk costs"; that is, investments in them have already been made, and only a small part of the investment can be recovered through salvage. These sunk costs should not be considered in determining whether to cease operation of a lighting installation. Whether an existing lighting installation should be closed down should be based on a comparison of its effectiveness (as measured, for example, by the numerator of the priority index number) and its annual maintenance and operating cost. Thus, an existing installation would not have to be as effective to continue its operation as would a new installation to justify its total cost. Nevertheless, an existing lighting system should give more benefits per dollar of operation that can be gotten from any other highway maintenance and operations expenditures that are foregone because of operating the lighting system. Also, new illumination projects should be cost effective when compared to other types of improvements.

If an illumination system is located in a city that is experiencing a severe shortage of electricity, such that the system is competing with essential services such as hospitals, homes, and manufacturing operations, careful consideration should be given to reducing or eliminating the lighting service, at least temporarily. This situation might result if there is another oil embargo or if there is a severe localized shortage because of supply problems in an area. Also, the possibility of such an occurrence and the current shortage of funds necessitates that careful consideration be given to the impact upon the total economy of the State before installing a facility that will be a continuing user of energy and in a real "crunch" will most certainly be among the first to be cut off.

## Background and State of the Art

The history of roadway lighting dates back to the 1400's when people in Paris and London began using lanterns to light the streets (1). This practice became popular and spread throughout Europe. The task of street lighting was first taken under government control in 1666. Progressive improvements were made from the first oil lamps to candle lanterns, sophisticated oil burners, gasoline street lamps, gas lamps, arc lamps, incandescent lamps, and finally to gaseous discharge lamps capable of lighting most, if not all, roadway facilities. In order of chronological development, the objectives of street and highway lighting can be listed as follows: crime reduction, civic improvement, and traffic safety.

Modern practice employs extensive technology in the areas of fixed lighting, benefits of these installations, and visual environments. However, there has been a lack of adequate research on fixed lighting warrants and priorities. The development of the first roadway lighting warrants was based primarily on engineering experience and judgment and was, therefore, extremely arbitrary. In the period 1955-1960, Rex (2, 3) initiated research to determine principles and factors of consideration in roadway lighting. A result of this work was the computation of both relative comfort and visibility factor ratings for lighting highways.

The Illuminating Engineering Society, in the middle 1960's, published the IES Lighting Handbook (7) which stated that roadway lighting should be planned on the basis of traffic information which includes the factors necessary to provide traffic safety and pedestrian security. Some of the warranting factors to be considered in the evaluation of a specific problem are:

1. Type of land use development abutting the roadway or walkway
2. Type of route
3. Traffic accident experience
4. Street crime experience and security requirements
5. Roadway construction features

Ketvirtis (8) presented a set of conditions that warrants illumination for fixed sources, based on 3 classes of lighting situations:

1. Class I, Partial Illumination. Luminaires are located only at critical decision points.

2. Class II, Intermediate Illumination. Luminaires are located as required by Class I, with additional units on the ramps connecting to lighted roadways or at intersections with lighted highways.

3. Class III, Full Illumination. Full illumination refers to complete lighting of facility, including all interchanges and at-grade intersections.

In addition to the three basic types of illumination, a four-level functional classification of the highway system is utilized. This classification consists of the following:

1. Freeway and expressway
2. Arterial
3. Collector
4. Local

Additional warranting conditions considered are ADT, distance between interchanges, roadside development, type of intersection, and accident rate.

In 1969, the American Association of State Highway Officials published what, at that time, was the most widely accepted set of warrants for roadway lighting (9). The informational guide cites the following conditions as those warranting roadway lighting:

1. Freeway Lighting -- Adjacent street grid system with lighting, developmental lighting, close interchange spacing, average daily traffic of 30,000 vehicles, high night-to-day accident experience, and willingness of local government to pay costs;

2. Interchange Lighting -- Adjacent lighting at the interchange and average daily traffic of 5,000 vehicles and more depending on the specific design; and

3. Roads Other than Freeways -- In general, locations where the respective governmental agencies concur that lighting will contribute substantially to the efficiency, safety, and comfort of vehicular and pedestrian traffic, and where resulting benefits, both tangible and intangible, are in the interest of the general public.

The information guide is used by most state highway departments.

Other research in the 1960's which discussed or evaluated roadway lighting warrants was by Knudson (10) in a comparison of street lighting codes. Rowan and Walton (11) studied the optimization of roadway lighting through the improvement of uniformity.

In 1971, Walton and McFarland (12) continued study into the analysis of roadway lighting alternatives by economic and accident potential parameters. Also this same year, the Illuminating Engineering Society presented the American National Standard Practice for Roadway Lighting (13). The suggestions presented in the Standard Practice are used by most cities that have established lighting programs. The following conditions are listed which should be examined in warranting the need and, thus, justification for roadway lighting: types of land use development abutting the roadway or walkway (area classification), type of route (route classification), traffic accident experience, street crime experience and security, and roadway construction features.

Herendeen (14) established analysis and design procedures to determine highway lighting needs in a study in Pennsylvania in 1972. In 1973-74, Walton and Rowan (15, 16) conducted studies which resulted in a total design process of warranting and setting priorities for highway lighting. This process is based on information needs of night drivers as related to the complex interrelations which exist between visual information needs, warranting conditions for lighting, guidelines for lighting designs, and cost-effective priorities for fund expenditures. A framework of information needs produced by various traffic facility characteristics is established for development of the design process. The information needs are presented as the requirements to be satisfied by roadway lighting, and the traffic facility characteristics producing the needs serve as the warranting conditions for the installation of lighting. The number of warranting conditons is used as the determinant of design criteria and the basis for cost-effectiveness priorites. A priority model was developed based on lighting effectiveness, vehicles or people served, lighting intensity, roadway mileage, and total annual lighting costs. The priority model favors those facilities with high warranting conditions that can be lighted most economically. It can be summarized that this total design process and warranting procedure is a rational approach which can possibly be used to revise current practices.

This approach to warranting and setting priorities for lighting is used in the "Suggested Warrants--Priorities Process" section of this report.

## Opinionnaire

An opinionnaire was sent to each District Engineer as a part of this research effort. The opinionnaire consisted of six check-type questions and one "other comments" question. It is reproduced on the following pages with the results from the districts. The questions dealt with lighted miles of roadway, types of lighting systems, the effect of lighting on safety, warrants, and use of lighting.

The opinionnaire revealed widespread usage of lighting in the districts. Median mounted and staggered mounted systems are most popular with opposite mounted systems following. Mounting heights tend to be greater than 40 feet in height and fifteen districts use high mast lighting.

Most districts feel that lighting has a very significant effect on safety, especially safety (interchange) lighting. The present warrants in general are accepted as satisfactory, with nine districts indicating that present warrants are inapplicable to specific roadway situations. A majority of the districts favor increased use of safety (interchange) lighting and no change in policy for use of continuous lighting.

## Suggested Warrants

Walton and Rowan (16) developed a procedure by which warrants and

# ROADWAY LIGHTING AND WARRANTS

## OPINIONNAIRE

District Summary Date

1. Please give approximations of the following number of lighted roadway facilities in your District.

| | | |
|---|---|---|
| Controlled Access = | 459.1 | Miles |
| Non-Controlled Access = | 152.0 | Miles |
| Number of Intersections = | 752 | |
| Number of Interchanges = | 488 | |

2. Please indicate the following types of lighting systems employed in your District;

| | |
|---|---|
| Median Mounted | 22 |
| Staggered Mounted | 21 |
| Opposite Mounted | 8 |
| One Side Mounted | 17 |
| Mounting Height ≦ 40' | 21 |
| Mounting Height > 40' | 22 |
| High Mast | 15 |

3. In your judgment, what effect does the type of lighting indicated below have with respect to safety?

| | Continuous | Safety (Interchange) |
|---|---|---|
| No Effect | 0 | 0 |
| 0-50% Increase | 15 | 8 |
| 50-100% Increase | 6 | 17 |

4. In general, are your present roadway lighting warrants satisfactory?

Yes 22 No 2 No Response 1

5. Are there any roadway situations where these warrants seem inapplicable?

Yes 9 No 15 No Response 1

If yes, please briefly describe Responses deal primarily with exceptions to warrants for specific situations in rural areas, high accident potential areas, and the need to lower lumen requirements.

6. With reference to the type lighting indicated, please check your preference.

| | Continuous | Safety (Interchange) |
|---|---|---|
| Increased use of | 3 | 17 |
| Decreased use of | 6 | 1 |
| Complete elimination of | 0 | 0 |
| No change in policy for | 16 | 8 |

7. Briefly state any other comments, positive or negative, concerning roadway lighting and/or warrants. Need to add more safety lighting. Funding from State Fund is too dependent on accident history. We should convert to high pressure sodium. Need mechanism for paying for maintenance and operation in small urban areas. Need to light area immediately behind large overhead signs that are illuminated.

TABLE 1
CLASSIFICATION FOR CONTROLLED ACCESS
FACILITY (FREEWAY) LIGHTING

| CLASSIFICATION FACTOR | | RATING | | | | | UNLIT WEIGHT (A) | LIGHTED WEIGHT (B) | DIFF. (A-B) | SCORE (RATING) X(A-B) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | | | | |
| GEOMETRIC FACTORS | | | | | | | | | | |
| 1-GF | No. of Lanes | | | 4 | 6 | 8 | 10.0 | 8.0 | 2.0 | |
| 2-GF | Lane Width | 12' | | 11' | | 10' | 3.0 | 2.5 | 0.5 | |
| 3-GF | Median Width | 40' | 24-39' | 12-23' | 4-11' | 0-3' | 1.0 | 0.5 | 0.5 | |
| 4-GF | Shoulders | 10' | 8' | 6' | 4' | 0' | 1.0 | 0.5 | 0.5 | |
| 5-GF | Slopes | 8:0 | 6:1 | 4:1 | 3:1 | 2:1 | 1.0 | 0.5 | 0.5 | |
| 6-GF | Curves | 0-½° | ½-1° | 1-2° | 2-3° | 3-4° | 10.0 | 8.0 | 2.0 | |
| 7-GF | Grades | 3% | 3-3.9% | 4-4.9% | 5-6.9% | >7% | 3.2 | 2.8 | 0.4 | |
| 8-GF | Interchange Freq. | 4 mi. | 3 mi. | 2 mi. | 1 mi. | <1 mi. | 4.0 | 1.0 | 3.0 | |
| | | | | | | | | GEOMETRIC TOTAL | | |
| OPERATIONAL FACTORS | | | | | | | | | | |
| 1-OF | Level of Service | A | B | B-C | C-D | D-E | 6.0 | 1.0 | 5.0 | |
| 2-OF | Total Night Volume per lane* | <1000 | 1000 | 2000 | 3000 | 4000 | 6.0 | 1.0 | 5.0 | |
| | | | | | | | | OPERATIONAL TOTAL | | |
| ENVIRONMENTAL FACTORS | | | | | | | | | | |
| 1-EF | % Development | 0% | 25% | 50% | 75% | 100% | 3.5 | 0.5 | 3.0 | |
| 2-EF | Offset to Develop from Traffic Lanes** | 200' | 150' | 100' | 50' | <50' | 3.5 | 0.5 | 3.0 | |
| | | | | | | | | ENVIRONMENTAL TOTAL | | |
| ACCIDENTS | | | | | | | | | | |
| 1-AF | Ratio of night to day accident rates | <1.0 | 1.0-1.1 | 1.1-1.2 | 1.2-1.5 | >1.5** | 10.0 | 2.0 | 8.0 | |
| | | | | | | | | ACCIDENT TOTAL | | |

*Total night volume on all lanes divided by number of lanes.
**Continuous lighting warranted

GEOMETRIC TOTAL = ______

OPERATIONAL TOTAL = ______

ENVIRONMENTAL TOTAL = ______

ACCIDENT TOTAL = ______

SUM = ______ POINTS

WARRANTING CONDITION = 100 POINTS

TABLE 2

CLASSIFICATION FOR INTERCHANGE LIGHTING

| CLASSIFICATION FACTOR | | RATING 1 | 2 | 3 | 4 | 5 | UNLIT WEIGHT (A) | LIGHTED WEIGHT (B) | DIFF. (A-B) | SCORE (RATING) X(A-B) |
|---|---|---|---|---|---|---|---|---|---|---|
| GEOMETRIC FACTORS* | | | | | | | | | | |
| 1-GF | Ramp Types | Direct | Diamond | Button Hooks Cloverleafs | Trumpet | Scissors and Left side | 2.0 | 1.0 | 1.0 | ______ |
| 2-GF | Cross Road Channelization | None | | Continuous | | At Interchange Intersections | 2.0 | 1.0 | 1.0 | ______ |
| 3-GF | Frontage Roads | None | | One-way | | Two-way | 1.5 | 1.0 | 0.5 | ______ |
| 4-GF | Freeway Lane Widths | 12 | | 11 | | 10 | 3.0 | 2.5 | 0.5 | ______ |
| 5-GF | Freeway Median Widths | > 40 | 24-40 | 12-24 | 4-12 | < 4 | 1.0 | 0.5 | 0.5 | ______ |
| 6-GF | No. Freeway Lanes | 4 or less | | 6 | | 8 or more | 10.0 | 8.0 | 2.0 | ______ |
| 7-GF | Main Lane Curves | ½° | 1-2° | 2-3° | 3-4° | 4° | 10.0 | 8.0 | 2.0 | ______ |
| 8-GF | Grades | 3% | 3-3.9% | 4-4.9% | 5-6.0% | 7% or more | 3.2 | 2.8 | 0.4 | ______ |
| 9-GF | Sight Dist. Cross Road Intersection | 1000' | 700-1000' | 500-700' | 400-500' | < 400' | 2.0 | 1.8 | 0.2 | ______ |
| | | | | | | | | GEOMETRIC TOTAL | | ______ |
| OPERATIONAL FACTORS | | | | | | | | | | |
| 1-OF | Level of Service | A | B | B-C | C-D | D-E | 6.0 | 1.0 | 5.0 | ______ |
| 2-OF | Total Night Volume per Lane** | < 1000 | 1000 | 2000 | 3000 | 4000 | 6.0 | 1.0 | 5.0 | ______ |
| | | | | | | | | OPERATIONAL TOTAL | | ______ |
| ENVIRONMENTAL FACTORS | | | | | | | | | | |
| 1-EF | % Development | None | 1 quad | 2 quad | 3 quad | 4 quad | 2.0 | 0.5 | 1.5 | ______ |
| 2-EF | Set-Back Distance From Traffic Lanes | > 200' | 150-200' | 100-150' | 50-100' | < 50' | 0.5 | 0.3 | 0.2 | ______ |
| 3-EF | Cross-Road Approach Lighting | None | | Partial | | Complete | 3.0 | 2.0 | 1.0 | ______ |
| 4-EF | Freeway Lighting | None | | Interchanges Only | | Continuous*** | 5.0 | 3.0 | 2.0 | ______ |
| | | | | | | | | ENVIRONMENTAL TOTAL | | ______ |
| ACCIDENTS | | | | | | | | | | |
| 1-AF | Ratio of night to day accident rates | < 1.0 | 1.0-1.1 | 1.1-1.2 | 1.2-1.5 | > 1.5*** | 10.0 | 2.0 | 8.0 | ______ |
| | | | | | | | | ACCIDENT TOTAL | | ______ |

*All four-level interchanges warrant lighting.
**Total night volume on all lanes divided by number of lanes.
***Complete lighting warranted.

GEOMETRIC TOTAL = ______

OPERATIONAL TOTAL = ______

ENVIRONMENTAL TOTAL = ______

ACCIDENT TOTAL = ______

SUM = ______ Points

COMPLETE LIGHTING WARRANTING CONDITION = 75 Points

PARTIAL LIGHTING WARRANTING CONDITION = 50 Points

TABLE 3

CLASSIFICATION FOR NON-CONTROLLED ACCESS FACILITY LIGHTING

| | CLASSIFICATION FACTOR | RATING 1 | 2 | 3 | 4 | 5 | UNLIT WEIGHT (A) | LIGHTED WEIGHT (B) | DIFF. (A-B) | SCORE (RATING) X(A-B) |
|---|---|---|---|---|---|---|---|---|---|---|
| GEOMETRIC FACTORS | | | | | | | | | | |
| 1-GF | No. of Lanes | 4 or less | | 6 | | 8 or more | 10.0 | 8.0 | 2.0 | ______ |
| 2-GF | Lane Width | 12' | | 11' | | 10' | 3.0 | 2.5 | 0.5 | ______ |
| 3-GF | Median Openings per mile | 4 or one way operation | 4-8 | 8-12 | 12-15 | 15 or no access control | 5.0 | 3.0 | 2.0 | ______ |
| 4-GF | Curb Cuts | < 10% | 10-20% | 20-30% | 30-40% | > 40% | 5.0 | 3.0 | 2.0 | ______ |
| 5-GF | Curves | 0°-.5° | .5°-1° | 1°-2° | 2°-3° | > 3° | 10.0 | 8.0 | 2.0 | ______ |
| 6-GF | Grades | < 3% | 3.0-3.9% | 4.0-4.9% | 5.0-6.9% | 7% or more | 3.2 | 2.8 | 0.4 | ______ |
| 7-GF | Sight Distance | 700' | 500-700' | 300-500' | 200-300' | < 200' | 2.0 | 1.8 | 0.2 | ______ |
| 8-GF | Parking | prohibited both sides | loading zones only | off-peak only | permitted one side | permitted both sides | 2.0 | 1.5 | 0.5 | ______ |
| | | | | | | | GEOMETRIC TOTAL | | | ______ |
| OPERATIONAL FACTORS | | | | | | | | | | |
| 1-OF | Signals | 100% intersections signalized | 100%-80% intersections signalized | 80%-60% intersections signalized | 60%-40% intersections signalized | < 40% intersections signalized | 3.0 | 2.5 | 0.5 | ______ |
| 2-OF | Left Turn Lane | 100% intersections or one way operation | 100%-80% intersections | 80%-60% intersections | 60%-40% intersections | < 40% turn bays or undivided streets | 5.0 | 4.0 | 1.0 | ______ |
| 3-OF | Median Width | 30' | 20-30' | 10-20' | 4-10' | 0-4' | 1.0 | 0.5 | 0.5 | ______ |
| 4-OF | 85% Speed | 25 or less | 30 | 35 | 40 | 45 or greater | 3.0 | 1.0 | 2.0 | ______ |
| 5-OF | Pedestrian Traffic at night | very few or none | 0-50 | 50-100 | 100-200 | > 200 | 1.0 | 0.2 | 1.3 | ______ |
| 6-OF | Total ADT Per Lane | < 1,500 | 2,000 | 2,500 | 3,000 | > 3500 | 3.0 | 1.0 | 2.0 | ______ |
| | | | | | | | OPERATIONAL TOTAL | | | ______ |
| ENVIRONMENTAL FACTORS | | | | | | | | | | |
| 1-EF | % Development | 0 | 0-30% | 30-60% | 60-90% | 100% | 3.0 | 1.0 | 2.0 | ______ |
| 2-EF | Predominant Type Development | undeveloped or backup design | residential | half-residential and/or commercial | industrial or commercial | strip industrial or commercial | 1.0 | 0.5 | 0.5 | ______ |
| 3-EF | Setback Distance From Traffic Lanes | 200 | 150-200' | 100-150' | 50-100' | < 50' | 1.0 | 0.5 | 0.5 | ______ |
| 4-EF | Advertising or area lighting | None | 0-40% | 40-60% | 60-80% | essentially continuous | 3.0 | 1.0 | 2.0 | ______ |
| 5-EF | Raised Curb Median | None | continuous | at all intersections | at signalized intersections | random locations | 1.0 | 0.5 | 0.5 | ______ |
| 6-EF | Crime Rate | extremely low | lower than city aver. | city aver. | higher than city aver. | extremely high | 1.0 | 0.5 | 0.5 | ______ |
| | | | | | | | ENVIRONMENTAL TOTAL | | | ______ |
| ACCIDENTS | | | | | | | | | | |
| 1-AF | Ratio of night to day accident rates | < 1.0 | 1.0-1.1 | 1.1-1.2 | 1.2-1.5 | > 1.5* | 10.0 | 2.0 | 8.0 | ______ |
| | | | | | | | ACCIDENT TOTALS | | | ______ |

*Continuous lighting warranted

GEOMETRIC TOTAL = ______

OPERATIONAL TOTAL = ______

ENVIRONMENTAL TOTAL = ______

ACCIDENT TOTAL = ______

SUM = ______ Points

**WARRANTING CONDITIONS = 85 Points**

TABLE 4

CLASSIFICATION FOR INTERSECTION LIGHTING

| | CLASSIFICATION FACTOR | RATING 1 | 2 | 3 | 4 | 5 | UNLIT WEIGHT (A) | LIGHTED WEIGHT (B) | DIFF. (A-B) | SCORE (RATING) X (A-B) |
|---|---|---|---|---|---|---|---|---|---|---|
| GEOMETRIC FACTORS | | | | | | | | | | |
| 1-GF | Number of Legs | | 3 | 4 | 5 | 6 or more (including traffic circles) | 3.0 | 1.0 | 2.0 | ______ |
| 2-GF | Approach Lane Width | 12' | | 11' | | 10' | 3.0 | 2.5 | 0.5 | ______ |
| 3-GF | Designated Turn Lanes | No turn lanes | Left turn lanes on major legs | Left turn lanes on all legs, right turn lanes on major legs | Left and right turn lanes on major legs | Left and right turn lanes on all legs | 2.0 | 1.0 | 1.0 | ______ |
| 4-GF | Approach Sight | 700' | 500-700' | 300-500' | 200-300' | < 200' | 2.0 | 1.8 | 0.2 | ______ |
| 5-GF | Grades on Approach Streets | < 3% | 3.0-3.9% | 4.0-4.9% | 5.0-6.9% | 7% or more | 3.2 | 2.8 | 0.4 | ______ |
| 6-GF | Curvature on Approach Legs | 0°-.5° | .5°-1° | 1°-2° | 2°-3° | > 3° | 10.0 | 8.0 | 2.0 | ______ |
| 7-GF | Parking in Vicinity | Prohibited both sides | Loading zones only | Off-peak only | Permitted one side only | Permitted both sides | 0.2 | 0.1 | 0.1 | ______ |
| | | | | | | | GEOMETRIC TOTAL | | | ______ |
| OPERATIONAL FACTORS | | | | | | | | | | |
| 1-OF | 85% Speed on Approach Legs | 25 miles or less | 30 mph | 35 mph | 40 mph | 45 mph or greater | 3.0 | 1.0 | 2.0 | ______ |
| 2-OF | Type of Control | All phases signalized (incl. turn lane) | Left turn lane signal control | through traffic signal control only | 4 way stop | stop control to minor legs or no control | 3.0 | 2.5 | 0.5 | ______ |
| 3-OF | Signal Controlled Lanes | Left and right signal control | Left and right turn lane signal control on major legs | Left turn lane signal control on all legs | Left turn lane signal control on major legs | no turn lane control | 3.0 | 2.0 | 1.0 | ______ |
| 4-OF | Level of Service Load Factor | A 0.0 | A-B 0-0.1 | B-C 0.1-0.3 | C-D 0.3-0.7 | D-E 0.7-1.0 | 1.0 | 0.2 | 0.8 | ______ |
| 5-OF | Pedestrian Traffic at Night | Very few or none | 0-50 | 50-100 | 100-200 | > 200 | 1.5 | 0.5 | 1.0 | ______ |
| 6-OF | Total ADT per Approach Lane | < 1,500 | 2,000 | 2,500 | 3,000 | > 3,500 | 3.0 | 1.0 | 2.0 | ______ |
| | | | | | | | OPERATIONAL TOTAL | | | ______ |
| ENVIRONMENTAL FACTORS | | | | | | | | | | |
| 1-EF | Percent Adjacent Development | 0 | 0-30% | 30-60% | 60-90% | 100% | 3.0 | 1.0 | 2.0 | ______ |
| 2-EF | Predominant Development near Intersection | Undeveloped | Residential | 50% Residential - 50% industrial or commercial | Industrial or commercial | Strip industrial or commercial (no circuity) | 1.0 | 0.5 | 0.5 | ______ |
| 3-EF | Lighting Immediate Vicinity | none | 0-40% | 40-60% | 60-80% | 100% | 3.0 | 1.0 | 2.0 | ______ |
| 4-EF | Crime Rate | Extremely low | Lower than city aver. | City aver. | Higher than city aver. | Extremely high | 1.5 | 0.5 | 1.0 | ______ |
| | | | | | | | ENVIRONMENTAL TOTAL | | | ______ |
| ACCIDENT FACTORS | | | | | | | | | | |
| 1-AF | Ratio of night to day accident rates | 1.0 | 1.0-1.1 | 1.1-1.2 | 1.2-1.5 | > 1.5* | 10.0 | 2.0 | 8.0 | ______ |
| | | | | | | | ACCIDENT TOTAL | | | ______ |

*Intersection lighting warranted

GEOMETRIC TOTAL = ________

OPERATIONAL TOTAL = ________

ENVIRONMENTAL TOTAL = ________

ACCIDENT TOTAL = ________

SUM = ________ Points

WARRANTING CONDITION = 75 Points

priorities for roadway lighting were determined on the basis of geometric operational and environmental conditions producing visual needs. This procedure is illustrated in the following paragraphs and tables, and include suggestions made by D-8 for weighting factors.

Tables 1, 2, 3, and 4 represent the classification scheme for various functional facilities considered. The minimum warranting condition is the total effectiveness achieved by lighting a traffic facility with an average rating of three on the subjective scale of 1 to 5. For example, the minimum warranting condition for continuous arterial lighting (Table 1) is 85 points. These 85 points represent a facility where all geometric, operational, environmental and accident parameters have a rating of 3 (no. of lanes = 6, median width 10-20', % development = 30-60%, night to day accident rate = 1.2-1.5, etc.) The rating Number 3, multiplied by the unlighted weight for each parameter and summed, minus the rating number 3 multiplied by the lighted weight for each parameter and summed, equals the minimum warranting number of points. If a given continuous arterial traffic facility received a Number 3 rating for each and every geometric, operational, environmental and accident parameter, the facility would just meet the minimum requirements for lighting. Any combination of ratings that will produce a total warranting points exceeding the minimum (85 for continuous arterial lighting), serves as the basis for setting priorities.

## Priority Process

The extent to which the warranting points exceed the minimum warranting points serves as the basis for setting priorities. Priorities should also be related to the number of people that benefit from a lighting improvement. Therefore, the warranting number for a given traffic facility (unlighted vs. lighted conditions) represent the effectiveness that can be achieved through the provision of fixed lighting. A generalized model, therefore, for setting priorities would be:

$$PI = \frac{W \times NADT}{C}$$

where PI = priority index

W = warranting number for a given facility

NADT = night average daily traffic

C = cost of lighting improvement

For new installations, the cost of the lighting improvement, C, should be the annualized initial cost plus annual maintenance and operating costs. If, however, a district would like to compare the priorities of existing facilities, this same formula can be used, but C would only include the annual maintenance and operating costs, since the initial installation cost is a "sunk cost", as was mentioned in the introduction. Priority numbers derived in this way for existing facilities can be used together with judgment to determine priorities for operation in a severe energy-shortage situation.

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