Florida Department of TRANSPORTATION

Final Lighting Justification Report

Malabar Road (SR 514) PD&E Study
From East of Babcock Street (SR 507) to US 1
Brevard County, Florida

FPID: 430136-1-22-01

ETDM: 13026

The environmental review, consultation, and other actions required by applicable federal environmental laws for this project are being, or have been, carried out by the Florida Department of Transportation (FDOT) pursuant to 23 U.S.C. §327 and a Memorandum of Understanding (MOU) dated December 14, 2016 and executed by the Federal Highway Administration and FDOT.

May 2015

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EXECUTIVE SUMMARY

A lighting justification analysis and report were produced for the Malabar Road [State Road (SR) 514] Project Development and Environment (PD&E) study from Babcock Road (SR 507) [mile post (M.P.) 3.060] to US 1 (M.P. 6.698), located in Brevard County, Florida. The lighting justification analysis and report are part of the PD&E study requested by the Town of Malabar and the Space Coast Transportation Planning Organization (TPO) for the potential widening of Malabar Road (SR 514) between M.P. 3.060 to M.P. 6.698.

The results of this study have concluded that this section of Malabar Road (SR 514) satisfies the steps necessary to justify the installation of continuous highway lighting as outlined in the United States Department of Transportation (USDOT) Federal Highway Administration (FHWA) Warrants Analysis, National Cooperative Highway Research Program (NCHRP) Report 152, in accordance with the Highway Lighting Justification Procedure found in the Florida Department of Transportation (FDOT) Manual on Uniform Traffic Studies (MUTS), Chapter 15.

1.0 PROJECT OVERVIEW

1.1. Introduction

This report contains the results of a highway lighting justification analysis for the Malabar Road [State Road (SR) 514] Project Development and Environment (PD&E) study, from Babcock Street (SR 507) to US 1, in Brevard County, Florida. This analysis was performed to determine the need for highway lighting as part of the project's design process. The overall project length is approximately 3.64 miles.

This section of Malabar Road (SR 514) is a four-lane divided Urban Minor Arterial from mile post (M.P.) 3.060 to M.P. 3.218, then, it converts to a two-lane undivided Urban Minor Arterial from M.P. 3.218 to M.P. 6.698. The surrounding development (or land use) along the studied corridor is primarily residential with the exception of a strip of commercial use near the intersection of SR 514 and SR 507, and the Palm Bay Hospital located on the north side of Malabar Road (SR 514) near Medplex Parkway.

Figure 1 - Project Location Map

1.2. Existing Conditions

Table 1 - Summary of Existing Conditions Malabar Road (SR 514)

Characteristic	Observation
Limits	SR 507 (M.P. 3.060) – US 1 (M.P. 6.698)
Location	SR 507 to West of Medplex Parkway – City of Palm Bay, Brevard County; West of Medplex Parkway to US 1 - Town of Malabar, Brevard County
FDOT Roadway ID	70180000
Roadway Maintaining Agency	FDOT
Functional Classification	Four Lane divided Urban Minor Arterial from M.P. 3.060 to M.P. 3.218 Two Lane Undivided Urban Minor Arterial from M.P. 3.218 to M.P. 6.698
Speed Limits	M.P. 3.060 – M.P. 3.850 : 45 MPH M.P. 3.850 – M.P. 5.974 : 55 MPH M.P. 5.974 – M.P. 6.332 : 45 MPH M.P. 6.332 – M.P. 6.698 : 30 MPH
Adopted LOS	FDOT Standard: "D"; Brevard County Standard: "D"; City of Palm Bay Standard: "E" and Town of Malabar Standard: "D"
Strategic Intermodal System Facility	No
Signalized Intersections from West to East	1) SR 507 (M.P. 3.060) 2) US 1 (M.P. 6.698)
Land Uses	Predominantly residential use along the entire study corridor. Strip commercial use near the intersection of SR 514 and SR 507. Palm Bay Hospital on the north side of SR 514 near Medplex Parkway.
Pavement Width	13 foot wide travel lanes from M.P. 3.060 – M.P. 3.218 12 foot wide travel lanes from M.P. 3.218 – M.P. 6.698
Sidewalks	5' sidewalk present on the north and south sides of SR 514 from M.P. 3.060 to M.P. 3.224.
Parallel Parking	None
Bike Lanes	Undesignated bike lanes from M.P. 3.217 to M.P. 4.241
Hurricane Evacuation	SR 514 within the study limits is a hurricane evacuation route.

1.3. Purpose

The purpose of the highway lighting justification report is to determine if highway lighting is justified for the potential roadway widening improvements to the indicated section of Malabar Road (SR 514).

1.4. Procedure

The Florida Department of Transportation (FDOT) Manual on Uniform Traffic Studies (MUTS) dated January 2000, Chapter 15: *Highway Lighting Justification Procedure*, establishes a two-step procedure for analyzing and justifying the implementation of roadway lighting. The first step involves the use of the American Association of State Highway and Transportation Officials' (AASHTO) roadway lighting warrants to determine if roadway conditions for the project in concert with other factors are conducive for the consideration of highway lighting. Part of the first step is to obtain a Lighting Maintenance and Operations Agreement from the maintaining agency (Florida Administrative Code (FAC) Rule 14-64 *Illumination of the State Highway System*). If the AASHTO warrants and the conditions established by FAC Rule 14-64 are met, then a benefit-cost analysis (step two) should be performed. On December 31, 1996, FAC Rule 14-64 was repealed, and it is no longer in effect.

The AASHTO warrants provide a basis for roadway conditions under which lighting may be considered, but it doesn't describe the sites where lighting is specifically justified. Furthermore, the AASHTO warrants do not cover arterial roadways; therefore, the United States Department of Transportation (USDOT) Federal Highway Administration's (FHWA) National Cooperative Highway Research Program (NCHRP) Report No. 152 *Warrants for Highway Lighting* warranting procedure was used as the first step for this study.

The second step in this analysis is to determine if roadway lighting for the project is justified on the basis of a benefit-cost analysis. If the benefit-cost ratio is equal to 1.0 or more, then lighting is justified for high crash locations as identified by the State Safety office. At other locations, the benefit-cost ratio should be 2.0 or greater to justify the implementation of roadway lighting.

1.5. Special Considerations

Historical crash data for five (5) years between 2008 and 2012 was obtained from FDOT's Crash Analysis Reporting (CAR) system, for Malabar Road (SR 514) from M.P. 3.060 to US 1 M.P. 6.698. During this five-year period a total of 110 crashes were reported. Out of the total 110 reported crashes, thirty-four (34) crashes or 30.9% were reported during dusk, dawn or night lighting conditions.

1.6. Existing Lighting

There is existing standard overhead lighting in some areas along Malabar Road (SR 514). The light fixtures are located between:

- Babcock Street (SR 507) and Enterprise Avenue – North side of Malabar Road (SR 514)
- Weber Road to Sandy Creek Lane – South side of Malabar Road (SR 514)
- Weir Street and Glatter Road – South side of Malabar Road (SR 514)
- Marie Street and US 1- North Side of Malabar Road (SR 514)

The lighting along these segments is not 100% continuous. In addition, the existing overhead lighting along the corridor will most likely be impacted or removed to accommodate the future roadway widening. Therefore, for the purpose of this report, the study corridor will be treated as having unlighted lighting conditions.

2.0 LIGHTING WARRANTS AND ANALYSIS

2.1. AASHTO & USDOT FHWA Highway Lighting Warrants

AASHTO's *Roadway Lighting Design Guide* (dated 2005), referred to by FDOT's MUTS, contains specific warrants for the justification of roadway lighting along freeways, interchanges and tunnels, but it does not have specific warrants for the justification of roadway lighting along arterial roadways. The guide does state that roadway lighting should be provided if it will contribute substantially to the efficiency, safety and comfort of the motoring public.

SR 514 is an Urban Minor Arterial roadway and the AASHTO warrants are not applicable for this study. Therefore, the USDOT FHWA *Roadway Lighting Handbook* warranting procedure was adopted for this report.

USDOT FHWA *Roadway Lighting Handbook* (Implementation Package 78-15) states that roadway lighting may be provided for all major arterials in urbanized areas and for locations or sections of street and highways where the night-to-day crash rates are high (above 2.0). The handbook adopts the analytical approach of the illumination warrants from NCHRP Report No. 152: *Warrants for Highway Lighting.* In this report, the roadway lighting evaluation warrants are based on geometric, operational, environmental and night-to-day crash rate parameters. This procedure is presented in the USDOT FHWA Warrants Analysis section of this roadway lighting justification report.

2.2. Traffic Counts

Traffic counts were obtained from FDOT's Florida Traffic Online (2013). Traffic information for three (3) sites along the study corridor was available from this source at mileposts 3.568, 5.642 and 6.623. The counts were taken in August 13, 20013, and sunrise/sunset tables were consulted to determine that twilight hours were from 8:00 PM to 7:00 AM. This data is summarized in **Tables 2** and **3**. Refer to **Appendix A** for the raw traffic counts from FDOT's Florida Traffic Online (2013).

Table 2 - Daytime vs. Nighttime Traffic Volumes Comparison

Traffic Counter Location	Travel Direction	Daytime Traffic Volumes	Nighttime Traffic Volumes	Total Traffic	% ADT at Night
M.P. 3.568	Eastbound and Westbound	15,674	2,038	17,712	12%
M.P. 5.642	Eastbound and Westbound	8,917	1,273	10,190	12%
M.P. 6.623	Eastbound and Westbound	9,579	1,831	11,410	16%

Notes:

1) Counts were conducted on 8/13/2013.

2) Length of study area: 3.638 miles.

Table 3 - Average Annual Daily Traffic (AADT)

Traffic Counter Location	Travel Direction	AADT
M.P. 3.568	Eastbound and Westbound	18,500
M.P. 5.642	Eastbound and Westbound	10,600
M.P. 6.623	Eastbound and Westbound	11,800

2.3. Crash Data Analysis

Historical crash data for five (5) years between 2008 and 2012 was obtained from FDOT's CAR system for the length of the project. A detailed crash analysis conducted with this data is shown in **Appendix B**. During this five-year period a total of 110 crashes were reported. Out of the total 110 reported crashes, thirty-four (34) crashes or 30.9% were reported during dusk, dawn, or night lighting conditions. **Table 4** below summarizes the total number of crashes by three categories: 1) Property Damage Only (PDO) crashes; 2) Injury crashes and 3) Fatal crashes. During this five-year period, a total of two (2) fatal crashes were reported along the study corridor, but they both occurred during daylight conditions.

Table 4 - Total Number of Crashes by Category

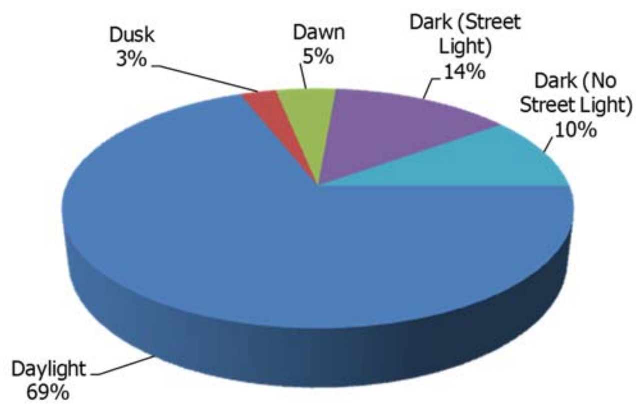
TOTAL NUMBER OF CRASHES												
	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Property Damage Only Crashes	14	45%	5	0%	9	0	10	36%	12	55%	50	45.5%
Injury Crashes	16	52%	9	0%	6	0	17	61%	10	45%	58	52.7%
Fatal Crashes	1	3%	0	0%	0	0	1	4%	0	0%	2	1.8%
Total	31	28%	14	13%	15	0	28	25%	22	20%	110	

Table 5 incorporates the total number of reported crashes for all the lighting conditions during the five-year period. This is graphically illustrated in **Figure 2**. For every year without exception, the majority of the crashes occurred during daylight conditions. The year 2008 had the highest number of reported crashes with a total of thirty-one (31). A total of two (2) fatal crashes were reported along the study corridor, but they both occurred during daylight conditions.

Table 5 - Total Number of Crashes by Lighting Condition

LIGHTING CONDITIONS (ALL)	2008	2009	2010	2011	2012	Total	
	#	#	#	#	#	#	%
Daylight	23	9	8	21	15	76	69.1
Dusk	1	0	0	2	0	3	2.7
Dawn	0	0	2	2	1	5	4.5
Dark (Street Light)	4	3	3	0	5	15	13.6
Dark (No Street Light)	3	2	2	3	1	11	10.0
Total	31	14	15	28	22	110	

Figure 2 - Lighting Conditions



In **Table 6**, the crash data was separated between daytime and nighttime crashes. During the 5-year period, a total of thirty-four (34) reported crashes occurred during nighttime. This equates to 30.9% of the total crashes.

Table 6 - Total Number of Crashes (Daytime vs. Nighttime)

LIGHTING (DAYTIME VS. NIGHTTIME)	2008	2009	2010	2011	2012	Total	
	#	#	#	#	#	#	%
Daytime	23	9	8	21	15	76	69.1
Nighttime	8	5	7	7	7	34	**30.9**
Total (Day & Night)	31	14	15	28	22	110	100%

Based on the above information, an annual average of 15.2 daytime crashes occurred along the study corridor during the 5-year period between 2008 and 2012. Conversely, during the nighttime period, the average dropped by more than half (when compared to the daytime annual average) at 6.8 crashes per year.

2.4. Crash Data Cost Summary

Per the FDOT 2014 Plans Preparation Manual (PPM), Volume 1, Chapter 23, Section 23.5, there are two acceptable methods for calculating a benefit/cost analysis:

1. Roadside Safety Analysis Program (RASP)
2. Historical Crash Method (HCM)

The second method is used at locations with a crash history as the name prescribes. The SR-514 (Malabar Road) corridor within the limits of this study (except for the first 835 feet at the beginning of the project) fits the 2-3 lane undivided urban facility type. Per the 'HSIPG COST/CRASH BY FACILTY TYPE' table presented on page 23-10 of the abovementioned PPM chapter and section, the cost per crash occurrence is calculated to be $114,040. Refer to Appendix C.

Average Cost per Crash: **$114,040**

2.5. Crash Rate Analysis

Crash rates are normally better indicators of risk than crash frequencies. Crash rates for roadway segments are typically expressed in terms of crashes per Million Vehicle Miles Traveled (MVMT), which is standard to the Traffic Engineering profession. The crash rate equation is shown below:

$$\mathbf{R}_{\mathbf{segment}} = \frac{\text{A x 1,000,000}}{\text{365 x T x V x L}}$$

Where:

R = Crash rate for the roadway segment/section

A = Number of reported crashes

T = Time period of the analysis (years)

V = Average daily traffic volume (ADT)

L = Length of the roadway segment (miles)

As presented in Section 3.2 (Traffic Counts) of this report, traffic information for three (3) sites along the study corridor was available at mileposts 3.568, 5.642 and 6.623. The traffic counter at M.P. 3.568 had the highest ADT at 17,712. This equates to a daytime ADT of 15,674 and a nighttime ADT of 2,038, as shown in Table 2. These two latter values are used in this study to calculate the 'nighttime' versus 'daytime' crash rates along the study corridor.

Daytime Crash Rate:

$$\mathbf{R_{segment}} = \frac{76 \times 1{,}000{,}000}{365 \times 5 \times 15{,}674 \times 3.638} = \mathbf{0.73} \text{ crashes per MVMT}$$

A = 76

T = 5

V = 15,674

L = 3.638

Nighttime Crash Rate:

$$\mathbf{R_{segment}} = \frac{34 \times 1{,}000{,}000}{365 \times 5 \times 2{,}038 \times 3.638} = \mathbf{2.51} \text{ crashes per MVMT}$$

A = 34

T = 5

V = 2,038

L = 3.638

Based on the above information, the 'Nighttime-to-Daytime' crash rate ratio can be calculated as follows:

$$\textbf{Night-to-Day Crash Rate Ratio} = \frac{\mathbf{2.51}}{\mathbf{0.73}} \boxed{= \mathbf{3.43}}$$

2.6. USDOT FHWA Warrants Analysis (NCHRP REPORT 152)

The Evaluation Form 1 for Non-Controlled Access Facility Lighting shown on the next page of this report comes from the USDOT FHWA Roadway Lighting Handbook NCHRP Report No. 152. It was specifically designed to analyze warranting conditions for the installation of lighting on non-controlled access facilities. The table provides the non-controlled access roadway facility a rating between 1 and 5 points based on the warranting condition, which is multiplied by a weighting factor. If the sum of all weighted ratings for the warranting conditions is 85 points, lighting is warranted.

The warranting form is divided into four classification factors; 1) Geometric, 2) Operational, 3) Environmental; and 4) Ratio of night-to-day crash rates. The form states that if the ratio of the night-to-day crash rate is 2.0 or greater, then continuous lighting is warranted (even if the overall score is less than 85 points). As calculated in the previous section, the night-to-day crash rate ratio for the study corridor is 3.43; therefore, continuous lighting is warranted. **Table 7** incorporates the factors that were used for the evaluation process based on the recommended alternative or 'Opening Day' conditions.

Table 7 - Malabar Road (SR 514) Evaluation Form 1 Classification Factors

Geometric Factors	
1. Number of Lanes:	4
2. Lane Width:	12 ft.
3. Median Openings per Mile:	<4.0 or one way operation
4. Curb Cuts:	10-20%
5. Curves:	<3.0 degrees
6. Grades:	<3%
7. Sight Distance:	300 - 500 ft.
8. Parking:	Prohibited both sides
Operational Factors	
1. Signals:	Most major intersection signalized
2. Left Turn Lane:	Most major intersections
3. Median Width:	20 - 30 ft.
4. Operating Speed:	45 or greater
5. Pedestrian traffic at Night (peds/mile):	0-50
Environmental Factors	
1. Percent Development:	30 - 60%
2. Predominant Type Development:	Half residential and/or half commercial
3. Setback Distance:	50 - 100 ft.
4. Adverting or Area Lighting:	0 - 40%
5. Raised Curb Median:	Continuous
6. Crime Rate:	City average
Crash Factor	
1. Ratio of Night-to-Day Crash Rates:	3.43

Figure 3 - NCHRP 152 – FORM 1

EVALUATION FORM 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									
No. of Lanes	4 or less	-	6	-	8 or more	1.0	0.8	0.2	0.2
Lane Width	>12'	12'	11'	10'	<10'	3.0	2.5	0.5	1.0
Median openings per mile	< 4.0 or one way operation	4.0-8.0	8.1-12.0	12.0-15.0	>15.0 or no access control	5.0	3.0	2.0	2.0
Curb Cuts	<10%	10-20%	20-30%	30-40%	>40%	5.0	3.0	2.0	4.0
Curves	<3.0°	3.1-6.0°	6.1-8.0°	8.1-10.0°	>10.0°	13.0	5.0	8.0	8.0
Grades	<3%	3.0-3.9%	4.0-4.9%	5.0-6.9%	7%or more	3.2	2.8	0.4	0.4
Sight Distance	>700'	500-700'	300-500'	200-300'	<200'	2.0	1.8	0.2	0.6
Parking	prohibited both sides	loading zones	off-peak only	permitted one side	permitted both sides	0.2	0.1	0.1	0.1
						Geometric Total			16.3
Operational Factors									
Signals	all major intersections signalized	substantial majority of intersections signalized	most major intersections signalized	about half the intersection signalized	frequent non-signalized interscions	3.0	2.8	0.2	0.6
Left turn lane	all major intersections or one way operation	substantial majority of intersections	most major intersections	about half the major intersections	infrequent turn bays or undivided streets	5.0	4.0	1.0	3.0
Median Width	30'	20-30'	10-20'	4-10'	0-4'	1.0	0.5	0.5	1.0
Operating Speed	25 or less	30	35	40	45 or greater	1.0	0.2	0.8	4.0
Pedestrian traffic at night (peds/mi)	very few or none	0-50	50-100	100-200	>200	1.5	0.5	1.0	2.0
						Operational Total			10.6
Environmental Factors									
% Development	0	0-30%	30-60%	60-90%	100.00%	0.5	0.3	0.2	0.6
Predominant Type Development	undeveloped or bakup design	residential	half-residential and/or commercial	industrial or commercial	strip industrial or commercial	0.5	0.3	0.2	0.6
Setback Distance	>200'	150-200'	100-150'	50-100'	<50'	0.5	0.3	0.2	0.8
Advertising or Area Lighting	none	0-40%	40-60%	60-80%	essentially continuous	3.0	1.0	2.0	4.0
Raised Curb Median	none	continuous	at all intersections	at signalized intersections	a few locations	1.0	0.5	0.5	1.0
Crime Rate	extremely low	lower than city aver.	city aver.	higher than city aver.	extremely high	1.0	0.5	0.5	1.5
						Environmental Total			8.5
Accidents									
Ratio of night to day accident rates	<1.0	1.0-1.2	1.2-1.5	1.5-2.0	2 *	10.0	2.0	8.0	40.0
						Accident Total			40.0

*Continuous lighting warranted

Geometric Total	16.3	
Operational Total	10.6	
Environmental Total	8.5	
Accident Total	40.0	
Sum	75.4	Points
Warranting Condition	85 points	

Continuous lighting warranted.

3.0 BENEFIT-COST RATIO ANALYSIS

The purpose of this step in the roadway lighting justification procedure is to determine if the project is justified based on its benefit-cost ratio. If the benefit-cost ratio is equal to 1.0 or more, then lighting is justified for high crash locations as identified by the State Safety office. At other locations the benefit-cost ratio should be 2.0 or greater.

The following equation is used to calculate the benefit-cost ratio:

$$\textbf{Benefit-Cost Ratio} = \frac{\text{ADT x \%ADTn x 365 x NRU x CRF x ACC}}{\text{(AIC + TMC + AEC) x 1,000,000}}$$

Where:

ADT = Average Daily Traffic (Existing or Projected)

%ADTn = Percent of ADT at night

NRU = Night crash rate unlighted

CRF = Crash reduction factor

ACC = Average crash cost (U.S. dollars per crash)

AIC = Annualized installation cost

TMC = Total annual maintenance cost

AEC = Annual energy cost

Annualized installation cost, total annual maintenance cost, and annual energy cost are expressed on a U.S. dollar per mile basis for mainline sections and as a total U.S. dollar value for interchanges. The annual lighting cost is the sum of electrical costs, maintenance costs, and installation costs of the proposed system only.

The average crash cost (ACC) was determined to be $114,040, as described in Section 3.4 of this report. Crash reduction factors (CRF) for various geometric configurations are present in Section 15.3.4 of the MUTS manual or as shown below in **Figure 8**. The CRF is a numerical value assigned to certain types of facilities and locations. It is based on an estimate of the crash reduction potential due to the installation of lighting. The CRF for Malabar Road (SR 514) along the PD&E study limits is 0.30.

Table 8 - Crash Reduction Factors

Site Description	CFR
Urban Freeway Interchange	0.80
Urban Freeway Mainline	0.20
Rural Freeway Interchange	0.80
Rural Freeway Mainline	0.20
Non-Controlled Access Roadways	
Rural Intersection	0.20
Rural Mainline	0.10
Urban Intersection	0.20
Urban Mainline (Commercial)	0.40
Urban Mainline (25% Commercial)	0.30
Urban Mainline (5% Commercial)	0.20

Design considerations, assumptions and historical values:

- New lighting system install
- ADT: 17,712
- Segment length: 3.638 miles or 19,209 ft.
- Poles on both sides
- Pole spacing: 200 ft.
- Pole height: 45 ft.
- Luminaries per pole: 1
- Luminaries wattage: 250
- Construction cost per pole: $7500
- Electrical cost: $.08/KWH
- Percent of ADT at night: 12%
- Night crash rate unlighted: 2.51 crashes per MVMT
- Average maintenance cost per luminary: $100/year
- A service life of 15 years is used in the capital recovery factor
- Interest rate: 10%

Capital Recovery (CRF, IR=10%, 15yr) $= \dfrac{(IR/100) \text{ x } (1 + (IR/100)^{15}}{(1 + ((IR/100)^{15}) - 1}$

Capital Recovery (CRF, IR=10%, 15yr) $= \dfrac{(10/100) \text{ x } (1 + (10/100)^{15}}{(1 + (10/100)^{15}) - 1}$

Capital Recovery (CRF, IR=10%, 15yr) = **0.1315**

$$\textbf{No. of Poles Req'd} = \frac{\text{Segment length (ft) x (1 pole) x (No. sides lighted)}}{\text{Spacing (ft)}}$$

$$\textbf{No. of Poles Req'd} = \frac{\text{19,209 (ft) x (1 pole) x (2 sides)}}{\text{200 (ft)}}$$

No. of Poles Req'd = 192

AIC = (Initial Cost/Pole) x (CRF) x (No. of Poles)

AIC = 7,500 x 0.1315 x 192

AIC = $189,360

TMC = (No. of Poles) x (Luminaries/Pole) x (Annual Maint. Cost/Luminary)

TMC = (192) x (1) x ($100)

TMC = $19,200

AEC = (No. of Poles) x (Luminaries/Pole) x (Watts/Luminary) x (KW/1000W)

x (Cents/KWH) x (11 Hours/Day) x ($1/100 Cents) x (365 Days/Year)

AEC = (192) x (1) x (250) x (1/1000) x (8) x (11) x (1/100) x (365)

AEC = $15,418

Therefore,

$$\textbf{Benefit-Cost Ratio} = \frac{\text{(17,712) x (0.12) x (365) x (2.51) x (0.30) x (\$114,040)}}{\text{(189,360 + 19,200 + 15,418) x (1,000,000)}}$$

Benefit-Cost Ratio = 0.297

4.0 RECOMMENDATION

Two procedures have been utilized for determining if roadway lighting is justified on Malabar Road (SR 514) within the project limits. The two procedures used for the analysis are the USDOT FHWA *Roadway Lighting Handbook* (NCHRP Report No. 152: *Warrants for Highway Lighting)* and the MUTS benefit-cost ratio analysis procedure.

The USDOT FHWA analytical evaluation form (NCHRP 152 – Form 1) meets the warranting condition for roadway lighting based on a ratio of night-to-day crash rate higher than 2.0 at 3.43.

The MUTS benefit-cost ration analysis calculated value of 0.297 does not exceed the minimum '2.0 or greater' benefit-cost ratio required to justify continuous lighting.

It is recommended that continuous roadway lighting be provided on Malabar Road (SR 514) from Babcock Street (SR 507) to US 1.

APPENDICES

Appendix A
FDOT's Florida Traffic Online (2013) Traffic Counts

Site Information	
Feature	**1**
Site	700379
Description	ON SR-514, 0.463 MI. E OF SR-507 (UVL)
Section	70180000
Milepoint	3.568
AADT	**18500**
Site Type	Portable
Class Data	No
K Factor	9
D Factor	54.2
T Factor	6.7
TRAFFIC REPORTS (provided in format)	
Brevard County	**Annual Average Daily Traffic**
	Historical AADT Data
	Synopsis 700379-20130813

Print this window. Close this window.

COUNTY: 70
STATION: 0379
DESCRIPTION: ON SR-514, 0.463 MI. E OF SR-507 (UVL)
START DATE: 08/13/2013
START TIME: 1200

	DIRECTION: E					DIRECTION: W					COMBINED
TIME	1ST	2ND	3RD	4TH	TOTAL	1ST	2ND	3RD	4TH	TOTAL	TOTAL
0000	14	12	10	10	46	17	13	17	9	56	102
0100	7	13	6	5	31	15	8	13	11	47	78
0200	18	5	5	5	33	12	6	8	4	30	63
0300	2	2	4	9	17	9	4	4	6	23	40
0400	6	7	13	13	39	8	6	14	8	36	75
0500	16	19	27	38	100	11	23	31	35	100	200
0600	37	76	129	167	409	44	56	74	85	259	668
0700	137	138	178	207	660	125	144	166	162	597	1257
0800	224	179	185	167	755	152	147	109	145	553	1308
0900	156	138	136	153	583	124	130	123	148	525	1108
1000	108	139	140	115	502	134	136	134	132	536	1038
1100	107	112	114	124	457	143	130	115	143	531	988
1200	125	123	121	118	487	149	146	149	166	610	1097
1300	143	131	124	130	528	129	114	146	154	543	1071
1400	132	127	149	141	549	132	153	152	121	558	1107
1500	123	128	135	170	556	166	155	156	186	663	1219
1600	152	167	151	145	615	224	170	183	212	789	1404
1700	127	174	147	141	589	223	234	189	186	832	1421
1800	143	137	146	126	552	183	151	134	119	587	1139
1900	113	103	77	86	379	132	113	126	99	470	849
2000	90	63	64	63	280	90	86	72	63	311	591
2100	49	55	46	66	216	64	45	42	38	189	405
2200	54	29	32	36	151	37	44	29	27	137	288
2300	23	25	19	21	88	31	31	27	19	108	196
24-HOUR TOTALS:					8622					9090	17712

PEAK VOLUME INFORMATION

	DIRECTION: E		DIRECTION: W		COMBINED DIRECTIONS	
	HOUR	VOLUME	HOUR	VOLUME	HOUR	VOLUME
A.M.	745	795	730	627	730	1415
P.M.	1545	640	1645	858	1645	1451
DAILY	745	795	1645	858	1645	1451

GENERATED BY SPS 5.0.44P

Site Information	
Feature	**1**
Site	700127
Description	ON SR-514, 1.097 MI. W OF SR-5 (US-1) (U VL)
Section	70180000
Milepoint	5.642
AADT	**10600**
Site Type	Portable
Class Data	No
K Factor	9
D Factor	54.2
T Factor	6.7
TRAFFIC REPORTS (provided in format)	
Brevard County	**Annual Average Daily Traffic**
	Historical AADT Data
	Synopsis 700127-20130813

Print this window. Close this window.

COUNTY: 70
STATION: 0127
DESCRIPTION: ON SR-514, 1.097 MI. W OF SR-5 (US-1) (UVL)
START DATE: 08/13/2013
START TIME: 1330

	DIRECTION: E					DIRECTION: W					COMBINED
TIME	1ST	2ND	3RD	4TH	TOTAL	1ST	2ND	3RD	4TH	TOTAL	TOTAL
0000	8	13	11	13	45	10	6	6	5	27	72
0100	3	12	5	9	29	3	6	3	3	15	44
0200	4	2	5	3	14	4	1	3	1	9	23
0300	8	0	6	2	16	1	1	5	5	12	28
0400	6	5	7	5	23	5	7	10	11	33	56
0500	9	15	18	23	65	16	16	33	29	94	159
0600	23	49	48	57	177	37	61	105	109	312	489
0700	70	53	68	76	267	109	133	164	153	559	826
0800	60	64	56	73	253	176	124	120	115	535	788
0900	54	78	59	58	249	84	81	86	81	332	581
1000	68	48	64	61	241	69	81	97	66	313	554
1100	63	69	53	75	260	64	58	77	74	273	533
1200	65	62	72	89	288	72	57	80	71	280	568
1300	74	68	71	57	270	76	82	78	80	316	586
1400	80	96	59	74	309	78	66	79	73	296	605
1500	75	77	99	104	355	75	89	82	98	344	699
1600	94	107	129	116	446	77	99	91	83	350	796
1700	116	117	129	83	445	81	100	75	88	344	789
1800	95	83	90	79	347	88	76	64	68	296	643
1900	64	71	58	45	238	58	58	51	55	222	460
2000	64	48	41	44	197	37	27	38	29	131	328
2100	51	33	22	28	134	35	25	32	33	125	259
2200	27	24	24	23	98	24	22	20	17	83	181
2300	25	21	13	16	75	17	8	12	11	48	123
24-HOUR TOTALS:					4841					5349	10190

PEAK VOLUME INFORMATION

	DIRECTION: E		DIRECTION: W		COMBINED DIRECTIONS	
	HOUR	VOLUME	HOUR	VOLUME	HOUR	VOLUME
A.M.	730	268	715	626	730	885
P.M.	1630	478	1545	365	1630	833
DAILY	1630	478	715	626	730	885

GENERATED BY SPS 5.0.44P

Site Information	
Feature	**1**
Site	701001
Description	ON SR-514, 0.119 MI. W OF US-1 (UCLP)
Section	70180000
Milepoint	6.623
AADT	**11800**
Site Type	Portable
Class Data	Yes
K Factor	9
D Factor	54.2
T Factor	5.6
TRAFFIC REPORTS (provided in format)	
Brevard County	Annual Average Daily Traffic
	Annual Vehicle Classification
	Historical AADT Data
	Synopsis 701001CL-20130813
	Vehicle Class History

Print this window. Close this window.

COUNTY: 70
STATION: 1001
DESCRIPTION: ON SR-514, 0.119 MI. W OF US-1 (UCLP)
START DATE: 08/13/2013
START TIME: 1315

	DIRECTION: E					DIRECTION: W					COMBINED
TIME	1ST	2ND	3RD	4TH	TOTAL	1ST	2ND	3RD	4TH	TOTAL	TOTAL
0000	9	8	7	4	28	9	14	10	13	46	74
0100	2	6	2	3	13	7	12	8	6	33	46
0200	3	1	3	1	8	4	3	4	4	15	23
0300	1	0	6	5	12	7	1	5	3	16	28
0400	4	9	12	10	35	6	5	6	6	23	58
0500	19	15	32	33	99	11	17	16	21	65	164
0600	40	63	116	116	335	28	53	55	55	191	526
0700	106	143	155	180	584	74	66	78	102	320	904
0800	180	127	129	117	553	74	65	76	65	280	833
0900	87	92	88	79	346	72	89	90	67	318	664
1000	74	79	95	77	325	77	68	62	76	283	608
1100	64	62	71	80	277	69	73	78	77	297	574
1200	65	65	94	70	294	80	74	92	93	339	633
1300	89	84	71	79	323	91	94	97	65	347	670
1400	73	70	85	72	300	97	111	79	100	387	687
1500	72	85	83	95	335	105	100	118	130	453	788
1600	79	95	98	88	360	139	127	178	160	604	964
1700	81	92	81	86	340	188	180	172	152	692	1032
1800	88	83	74	64	309	137	90	102	88	417	726
1900	67	59	56	51	233	67	74	65	57	263	496
2000	46	25	35	29	135	60	55	45	42	202	337
2100	36	24	31	30	121	52	36	38	21	147	268
2200	23	23	24	13	83	30	20	24	23	97	180
2300	19	9	12	11	51	23	21	16	16	76	127
24-HOUR TOTALS:					5499					5911	11410

PEAK VOLUME INFORMATION

	DIRECTION: E		DIRECTION: W		COMBINED DIRECTIONS	
	HOUR	VOLUME	HOUR	VOLUME	HOUR	VOLUME
A.M.	715	658	700	320	715	978
P.M.	1545	367	1630	706	1630	1065
DAILY	715	658	1630	706	1630	1065

TRUCK PERCENTAGE 5.49 5.77 5.64

CLASSIFICATION SUMMARY DATABASE

DIR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTTRK	TOTVOL
E	56	3999	1142	25	182	35	0	36	24	0	0	0	0	0	0	302	5499
W	33	4495	1042	27	205	31	4	43	31	0	0	0	0	0	0	341	5911

GENERATED BY SPS 5.0.44P

Appendix B

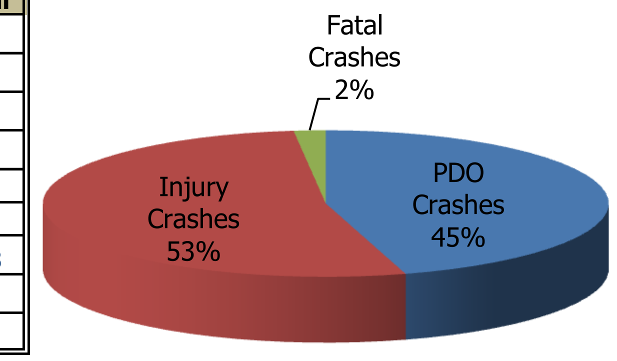
5-Year Crash Analysis

5-Year Crash Analysis SR 514 (Malabar Road)
From SR 507 (Babcock Street) to US 1
(MP 3.060 to MP 6.698)

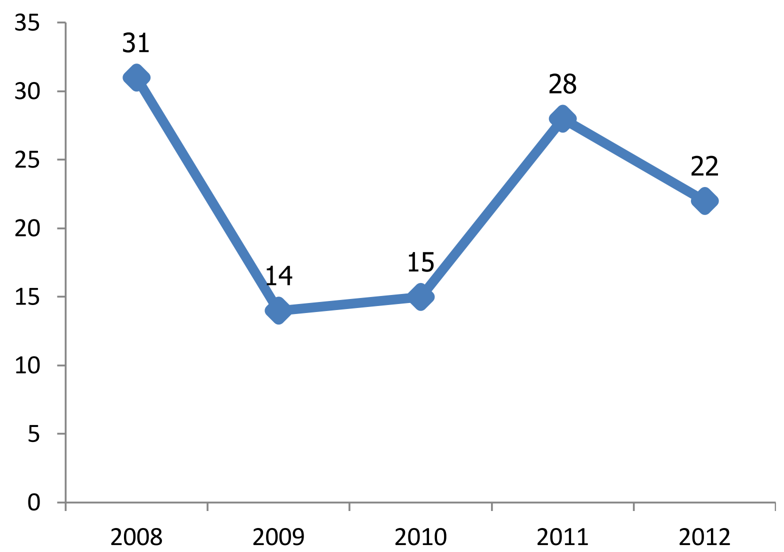
TOTAL NUMBER OF CRASHES	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Property Damage Only (PDO) Crashes	14	45%	5	0%	9	0%	10	36%	12	55%	50	45.5
Injury Crashes	16	52%	9	0%	6	0%	17	61%	10	45%	58	52.7
Fatal Crashes	1	3%	0	0%	0	0%	1	4%	0	0%	2	1.8
Total	31	28%	14	13%	15	0%	28	25%	22	20%	110	
Increase/Decrease				-121%		7%		46%		-27%		

NUMBER OF VEHICLES INVOLVED	2008	2009	2010	2011	2012	Total
FATAL CRASHES	1	0	0	1	0	2
Fatalities	1	0	0	1	0	2
Injuries	0	0	0	1	0	1
INJURY CRASHES	16	9	6	17	10	58
Injuries	24	19	13	25	14	95
TOTAL # OF INJURED PEOPLE	24	19	13	26	14	96
TOTAL # OF VEH INVOLVED	64	29	26	52	37	208
INJURED + FATAL (TOTAL INVOLVED)	25	19	13	27	14	98
TOTAL PDO	14	5	9	10	12	50

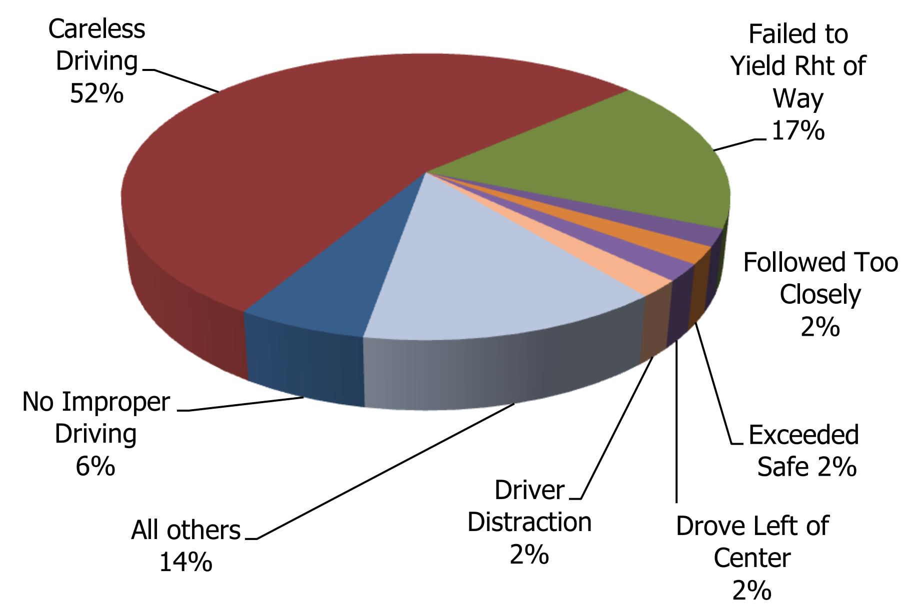
PERCENTAGE CRASH TYPE



TOTAL NUMBER OF CRASHES



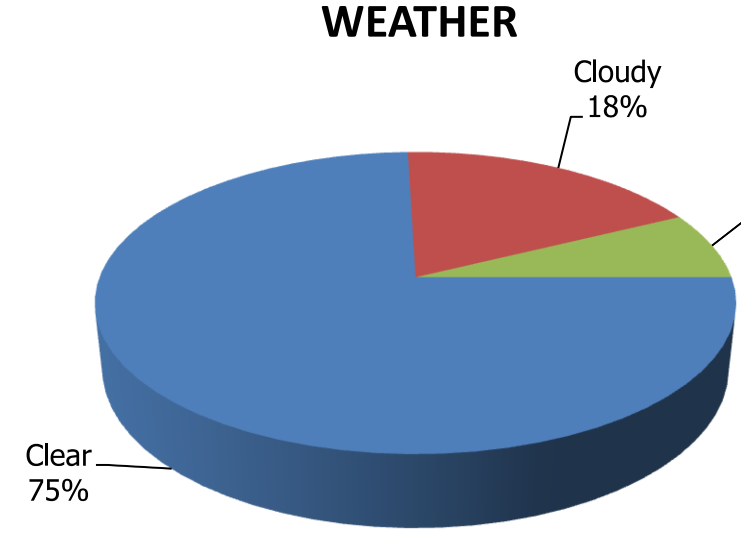
CONTRIBUTING CAUSE



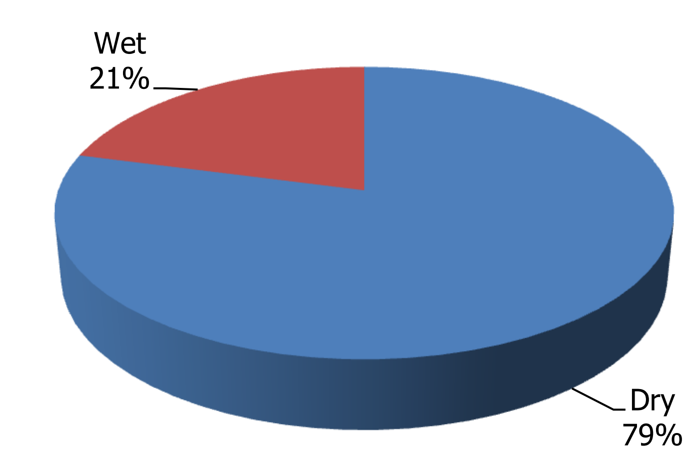
CONTRIBUTING CAUSE	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
No Improper Driving			1	7%			2	8%	3	14%	6	5.6
Careless Driving	16	52%	9	64%	9	60%	13	50%	9	41%	56	51.9
Failed to Yield Rht of Way	3	10%	3	21%	5	33%	5	19%	2	9%	18	16.7
Improper Parking	1	3%									1	0.9
Improper Lane Change												
Improper Turn	1	3%									1	0.9
Alcohol-Under Influence												
Drugs - Under Influence												
Alcohol/Drugs												
Followed Too Closely							1	4%	1	5%	2	1.9
Disregarded Traffic Signal												
Exceeded Safe Speed							1	4%	1	5%	2	1.9
Disregarded Stop Sign	1	3%									1	0.9
Failed to Maintain Equip												
Improper Passing	1	3%									1	0.9
Drove Left of Center	2	6%									2	1.9
Exceeded Stated Speed Limit												
Obstructing Traffic												
Improper Load	1	3%									1	0.9
Disregarded Other Traffic Control									1	5%	1	0.9
Driving Wrong Side/Way												
Fleeing Police												
Vehicle Modified												
Driver Distraction	1	3%			1	7%					2	1.9
All others	4	13%	1	7%			4	15%	5	23%	14	13.0
Total	31	29%	14	0%	15	0%	26	24%	22	20%	108	

FIRST HARMFUL EVENT	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Coll Rear End	13	42%	6	43%	5	33%	8	31%	10	45%	42	38.9
Coll Head On							1	4%	1	5%	2	1.9
Coll Angle	3	10%	3	21%	3	20%	7	27%	2	9%	18	16.7
Coll Left Turn	2	6%	1	7%	1	7%					4	3.7
Coll Right Turn	1	3%	1	7%							2	1.9
Coll Sideswipe	1	3%									1	0.9
Coll Backed Into	1	3%									1	0.9
Coll Parked Car												
Coll MV on Roadway							1	4%	1	5%	2	1.9
Coll w/ Pedestrian	1	3%							1	5%	2	1.9
Coll w/ Bycicle												
Coll w/ Bycicle (Bike Lane)												
Coll w/ Moped												
Coll w/ Train												
Coll w/ Animal									1	5%	1	0.9
MV Hit Sign/Sign Post												
MV Hit Utility Pole/Light Pole					2	13%	1	4%	2	9%	5	4.6
MV Hit Guardrail									1	5%	1	0.9
MV Hit Fence	1	3%									1	0.9
MV Hit Concrete Barrier Wall												
MV Hit Bridge/Pier/Abutment/Rail												
MV Hit Tree/Shrubbery	2	6%									2	1.9
Coll Const Barricade Sign												
Coll w/ Traffic Gate												
Coll w/ Crash Attenuators												
Coll w/ Fixed Objects Above Road												
MV Hit Other Fixed Objects												
Coll w/ Moveable Object on Road												
MV Ran Into Ditch/Culvert	2	6%	1	7%	2	13%	3	12%	2	9%	10	9.3
Ran Off Road Into Water												
Overturned							3	12%			3	2.8
Occupant Fell From Veh												
Tractor/Trailer Jackknifed												
Fire												
Explosion												
Downhill Runaway												
Cargo Loss or Shift	1	3%									1	0.9
Separation of Units			1	7%							1	0.9
Median Crossover												
All other	3	10%	1	7%	2	13%	2	8%	1	5%	9	8.3
Total	31	29%	14	0%	15	0%	26	24%	22	20%	108	

WEATHER



ROAD SURFACE CONDITION



ROAD SIDE	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Left	10	32%	8	57%	5	33%	11	39%	7	32%	41	37.3
Right	21	68%	6	43%	9	60%	16	57%	12	55%	64	58.2
Intersection												
Middle/Median												
Left side-road					1	7%	1	4%	2	9%	4	3.6
Right side-road									1	5%	1	0.9
End of State Road												
All Other												
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

ACCIDENT LANE NUMBER

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Acceleration/Merge lane												
Toll Plaza												
Painted Crosswalk												
End of State Road												
Island Area	1	3%									1	0.9
Service/Access Road												
Left Turn Lane					1	7%	1	4%	1	5%	3	2.7
Median/Middle												
Parking Lane												
Right Turn Lane	1	3%			3	20%	1	4%	1	5%	6	5.5
Side of the Road/Shoulder	10	32%	2	14%	4	27%	7	25%	6	27%	29	26.4
Continuous Turn Lane (Center)												
Unknown					2	13%					2	1.8
Bicycle Lane												
Ramp												
1: Thru-Lanes (numbered from center outward)	17	55%	12	86%	5	33%	19	68%	13	59%	66	60.0
2: Thru-Lanes (numbered from center outward)	1	3%									1	0.9
3: Thru-Lanes (numbered from center outward)	1	3%							1	5%	2	1.8
4: Thru-Lanes (numbered from center outward)												
5: Thru-Lanes (numbered from center outward)												
All Other												
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

ROAD CONDITION AT TIME OF CRASH

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
No Defects	30	97%	13	93%	15	100%	28	100%	20	91%	106	96.4
Obtruction with Warning												
Obtruction without Warning												
Road Under Repair/Construction	1	3%							1	5%	2	1.8
Loose Surface Materials												
Shoulders Soft/Low/High												
Holes/Ruts/Unsafe Paved Edge												
Standing Water			1	7%					1	5%	2	1.8
Worn / Polished Road Surface												
All Others												
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

ROAD SURFACE CONDITION

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Dry	21	68%	11	79%	13	87%	25	89%	17	77%	87	79.1
Wet	10	32%	3	21%	2	13%	3	11%	5	23%	23	20.9
Slippery												
Icy												
All Other												
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

POINT OF IMPACT

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Front End	15	48%	6	43%	9	60%	14	54%	10	45%	54	50.0
Right Front End	1	3%			2	13%	1	4%	4	18%	8	7.4
Right Front Qtr Panel			1	7%			2	8%	2	9%	5	4.6
Right Front Door	2	6%			2	13%	1	4%			5	4.6
Right Rear Door							1	4%			1	0.9
Right Rear Qtr Panel												
Right Rear Corner	1	3%									1	0.9
Rear End												
Left Rear Corner												
Left Rear Qtr Panel	2	6%							1	5%	3	2.8
Left Rear Door									1	5%	1	0.9
Left Front Door							1	4%			1	0.9
Left Front Qtr Panel			1	7%			1	4%	1	5%	3	2.8
Left Front Corner	6	19%	4	29%	1	7%	2	8%	2	9%	15	13.9
Hood												
Roof												
Trunk												
Undercarriage												
Overturn	1	3%					3	12%			4	3.7
Windshield												
Trailer			1	7%							1	0.9
Unknown/Other	3	10%	1	7%	1	7%			1	5%	6	5.6
Total	31	29%	14	13%	15	14%	26	24%	22	20%	108	

SITE LOCATION

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Not At Intersection / RR X-ring / Bridge	15	48%	7	50%	3	20%	8	29%	7	32%	40	36.4
At Intersection	14	45%	7	50%	5	33%	11	39%	11	50%	48	43.6
Influenced By Intersection	1	3%			5	33%	6	21%	3	14%	15	13.6
Driveway Access	1	3%			1	7%	3	11%	1	5%	6	5.5
Railroad					1	7%					1	0.9
Bridge												
Entrance Ramp												
Exit Ramp												
Parking Lot-Public												
Parking Lot-Private												
Private Property												
Toll-Booth												
Public Bus Stop Zone												
All Other												
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

VEHICLE INVOLVEMENT

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
1 Veh Crash	7	23%	2	14%	5	33%	9	32%	7	32%	30	27.3
2 Veh Crash	17	55%	9	64%	9	60%	15	54%	15	68%	65	59.1
3 Veh Crash	5	16%	3	21%	1	7%	3	11%			12	10.9
4+ Veh Crash	2	6%					1	4%			3	2.7
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

VEHICLE USE

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Private Tranportation	29	94%	14	100%	15	100%	26	100%	19	86%	103	95.4
Commercial Passengers												
Commercial Cargo	2	6%									2	1.9
Public Transportation												
Public School Bus												
Private School Bus												
Ambulance												
Law Enforcement									1	5%	1	0.9
Fire/Rescue												
Military												
Other Government												
Dump												
Concrete Mixer												
Gargabe or Refuse												
Cargo Van												
Other									2	9%	2	1.9
Total	31	29%	14	13%	15	14%	26	24%	22	20%	108	

VEHICLE TYPE

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Automobile	16	52%	7	50%	9	60%	12	46%	12	55%	56	51.9
Van	2	6%	2	14%	1	7%	1	4%			6	5.6
Light Truck/ P.U. - 2 or 4 rear tires	10	32%	4	29%	5	33%	6	23%	9	41%	34	31.5
Medium Truck - 4 rear tires	1	3%									1	0.9
Heavy Truck - 2 or more rear axles	1	3%									1	0.9
Truck Tractor (Cab-Bobtail)												
Motor Home (RV)												
Bus (driver + seats for 9 - 15)												
Bus (driver + seats over 15)												
Bicycle												
Motorcycle	1	3%	1	7%			6	23%	1	5%	9	8.3
Moped												
All Terrain Vehicle												
Train												
Low Speed Vehicle												
Other							1	4%			1	0.9
Total	31	29%	14	13%	15	14%	26	24%	22	20%	108	

VEHICLE MOVEMENT

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Straight Ahead	21	68%	10	71%	9	60%	18	69%	16	73%	74	68.5
Slowing / Stopped / Stalled	2	6%					1	4%	2	9%	5	4.6
Making Left Turn	3	10%	3	21%	6	40%	4	15%	1	5%	17	15.7
Backing	1	3%									1	0.9
Making Right Turn	1	3%	1	7%			3	12%			5	4.6
Changing Lanes	1	3%							1	5%	2	1.9
Entering / Leaving Parking Space												
Property Parked												
Improperly Parked												
Making U-Turn												
Passing	2	6%									2	1.9
Driverless or Runaway Vehicle												
All Other									2	9%	2	1.9
Total	31	29%	14	13%	15	14%	26	24%	22	20%	108	

VEHICLE DIRECTION

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
North	4	13%			1	7%	1	4%	1	5%	7	6.4
South	1	3%	2	14%	3	20%	2	7%	1	5%	9	8.2
East	16	52%	5	36%	8	53%	9	32%	12	55%	50	45.5
West	10	32%	7	50%	3	20%	14	50%	8	36%	42	38.2
Unknown							2	7%			2	1.8
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

WEATHER

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Clear	19	61%	10	71%	13	87%	24	86%	16	73%	82	74.5
Cloudy	10	32%	2	14%	2	13%	4	14%	2	9%	20	18.2
Rain	2	6%	2	14%					4	18%	8	7.3
Fog												
All Other												
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

TIME OF DAY

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
1:00 AM			1	7%							1	0.9
2:00 AM	1	3%	1	7%			1	4%	1	5%	4	3.6
3:00 AM												
4:00 AM	1	3%					1	4%			2	1.8
5:00 AM	1	3%			1	7%	1	4%			3	2.7
6:00 AM	1	3%					1	4%	2	9%	4	3.6
7:00 AM	1	3%	1	7%	3	20%	3	11%	1	5%	9	8.2
8:00 AM	3	10%			1	7%	2	7%	2	9%	8	7.3
9:00 AM			2	14%					1	5%	3	2.7
10:00 AM												
11:00 AM	1	3%			2	13%	4	14%	1	5%	8	7.3
12:00 PM	1	3%					1	4%			2	1.8
1:00 PM			1	7%			2	7%	1	5%	4	3.6
2:00 PM	5	16%	1	7%			1	4%			7	6.4
3:00 PM	1	3%			1	7%	3	11%	2	9%	7	6.4
4:00 PM	5	16%	1	7%	1	7%	3	11%	2	9%	12	10.9
5:00 PM	4	13%	2	14%			1	4%	3	14%	10	9.1
6:00 PM	1	3%	2	14%	1	7%	1	4%	1	5%	6	5.5
7:00 PM	2	6%	1	7%	1	7%	1	4%	1	5%	6	5.5
8:00 PM							1	4%			1	0.9
9:00 PM	1	3%	1	7%	2	13%					4	3.6
10:00 PM	1	3%							1	5%	2	1.8
11:00 PM					1	7%	1	4%	3	14%	5	4.5
12:00 AM	1	3%			1	7%					2	1.8
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

LIGHTING

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Daylight	23	74%	9	64%	8	53%	21	75%	15	68%	76	69.1
Dusk	1	3%					2	7%			3	2.7
Down					2	13%	2	7%	1	5%	5	4.5
Dark (Street Light)	4	13%	3	21%	3	20%			5	23%	15	13.6
Dark (No Street Light)	3	10%	2	14%	2	13%	3	11%	1	5%	11	10.0
Unknown												
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

MONTH

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
January	2	6%	1	7%			1	4%	1	5%	5	4.5
February	5	16%	3	21%			2	7%			10	9.1
March	4	13%	2	14%	5	33%	2	7%	2	9%	15	13.6
April	2	6%	2	14%	2	13%					6	5.5
May	2	6%	1	7%	2	13%	2	7%	2	9%	9	8.2
June	1	3%			1	7%	2	7%	2	9%	6	5.5
July	6	19%			2	13%	7	25%	3	14%	18	16.4
August			2	14%			4	14%	1	5%	7	6.4
September	3	10%					2	7%	4	18%	9	8.2
October	1	3%	2	14%	2	13%	4	14%	2	9%	11	10.0
November	3	10%					1	4%	2	9%	6	5.5
December	2	6%	1	7%	1	7%	1	4%	3	14%	8	7.3
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

AGE

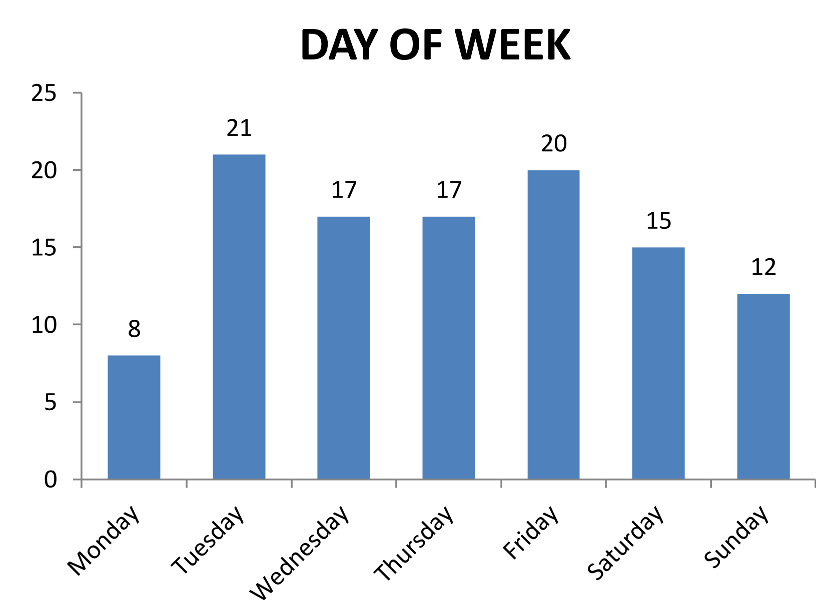
	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
16-25	7	23%	5	36%	7	47%	6	23%	6	27%	31	28.7
26-40	9	29%	2	14%	1	7%	7	27%	4	18%	23	21.3
41-65	9	29%	4	29%	3	20%	12	46%	7	32%	35	32.4
Over 65	1	3%	3	21%	2	13%	1	4%	4	18%	11	10.2
Unknown or Other	5	16%			2	13%			1	5%	8	7.4
Total	31	29%	14	13%	15	14%	26	24%	22	20%	108	

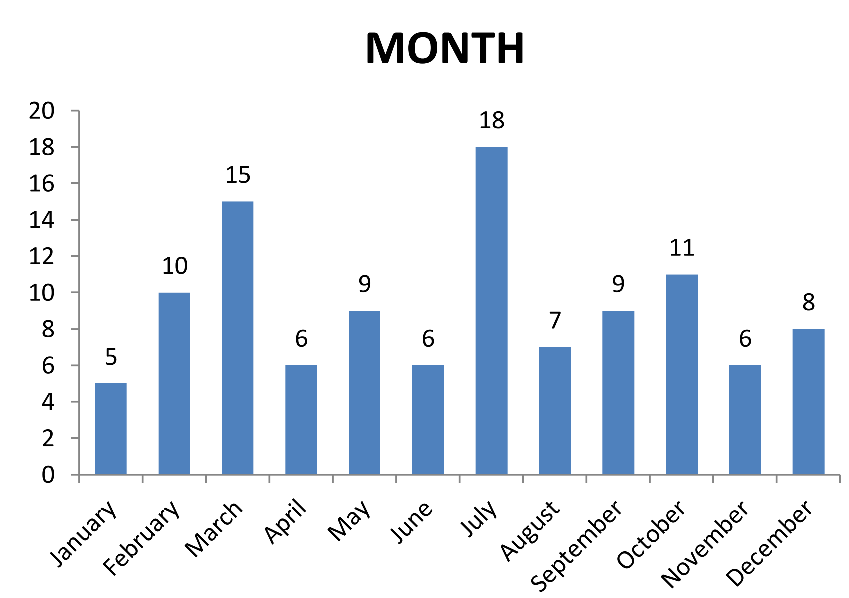
DAY OF THE WEEK

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Monday	4	13%			1	7%	2	7%	1	5%	8	7.3
Tuesday	5	16%	4	29%	4	27%	4	14%	4	18%	21	19.1
Wednesday	6	19%	1	7%	3	20%	3	11%	4	18%	17	15.5
Thursday	4	13%	3	21%	3	20%	5	18%	2	9%	17	15.5
Friday	6	19%	3	21%	2	13%	4	14%	5	23%	20	18.2
Saturday	5	16%					7	25%	3	14%	15	13.6
Sunday	1	3%	3	21%	2	13%	3	11%	3	14%	12	10.9
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	

ALCOHOL/DRUGS INVOLVEMENT

	2008		2009		2010		2011		2012		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
None	27	87%	11	79%	14	93%	25	89%	20	91%	97	88.2
Alcohol Involved	4	13%	3	21%	1	7%	2	7%	2	9%	12	10.9
Drugs Involved												
Alcohol and Drugs Involved							1	4%			1	0.9
Undetermined												
Total	31	28%	14	13%	15	14%	28	25%	22	20%	110	





Appendix C

FDOT 2017 Plans Preparation Manual, Volume 1, Chapter 23, Section 23.5

Topic #625-000-007

January 2013

Revised January 1, 2014

PLANS PREPARATION MANUAL

VOLUME 1

DESIGN CRITERIA AND PROCESS

FDOT

DESIGN

23.5 Documentation for Central Office Approval

During the justification process supporting documentation will be generated which needs to accompany each submittal. This documentation includes, but is not limited to the following:

All Design Variations needing Central Office approvals and all Design Exceptions should include the following documentation:

a) ***Exhibit 23-A*** Submittal/Approval Letter Included (Cover Letter)

b) Summary description of included support documentation such as:
   1) Location map or description,
   2) Typical section,
   3) Aerial or Photo logs when they best illustrate the element issues,
   4) Crash History and analysis,
   5) Plan sheets in the area of the Design Exception/Design Variation elements,
   6) Profiles in the area of vertical alignment Design Exception/Design Variation elements,
   7) Tabulation of pole offsets for horizontal clearance Design Exception/Design Variation, and
   8) Any Applicable Signed and Sealed Engineering Support Documents.

c) Project description (general project information, typical section, begin/end milepost, county section number). Include Work Mix, To – From, Objectives, Obstacles and Schedule.

d) Description of the Design Exception/Design Variation element and applicable criteria (AASHTO and Department value or standard). Detailed explanation of why the criteria or standard cannot be complied with or is not applicable. Description of any proposed value for project and why it is appropriate.

e) Amount and character of traffic using the facility. Description of the anticipated impact on Operations, Adjacent Sections, Level Of Service, Safety, Long and Short Term Effects. (Is the Design Exception temporary or permanent?) Description of the anticipated Cumulative Effects.

f) A plan view or aerial photo of the Design Exception location, showing right of way lines, and property lines of adjacent property.

g) A photo of the area.

h) Typical section or cross-section of Design Exception location.

i) The milepost and station location of the Design Exception.

j) Any related work programmed or in future work plans.

k) The Project Schedule Management (PSM) Project Schedule Activities maintained by the Finance Management Office.

l) All mitigating efforts. An explanation of what if any associated existing or future limitations as a result of public or legal commitments. Description and explanation of any practical alternatives, the selected treatment and why.

m) Comments on the most recent 5-year crash history including all pertinent crash reports.

n) Description of the anticipated Cost (Social and to the Department - Benefit/Cost)

o) Summary Conclusions

For the specified conditions the following additional documentation is required:

p) For design speed on SIS, provide typical sections at mid blocks and at intersections.

q) For lane width, provide locations of alternative routes that meet criteria and a proposal for handling drainage, the proposed signing and pavement markings.

r) For shoulder width, provide a proposal for handling stalled vehicles and a proposal for handling drainage.

s) For bridge width, provide a plan view of the approaching roadways and existing bridge plans (these may be submitted electronically).

t) For a bridge with a design inventory load rating less than 1.0, a written evaluation and recommendation by the Office of Maintenance is required. Provide the load rating calculations for the affected structure.

u) For vertical clearance, provide locations of alternative routes that meet criteria.

v) For cross-slope, provide a proposal for handling drainage and details on how the cross slope impacts intersections.

w) For conditions that may adversely affect the roadway's capacity, provide the comments on compatibility of the design and operation with the adjacent sections. Effects on capacity (proposed criteria vs. AASHTO) using an acceptable capacity analysis procedure and calculate reduction for design year, level of service).

x) For superelevation, provide the side friction factors for the curve for each lane of different cross-slope at the PC of the curve, the point of maximum cross-slope, and the PT of the curve using the following equation.

$$f = \frac{V^2 - 15Re}{V^2e + 15R}$$

where

f = Side Friction Factor
V = Design Speed (mph)
R = Radius (feet)
e = Superelevation (ft/ft) at the station evaluated

y) For areas with crash histories or when a benefit to cost analysis is requested, provide a time value analysis between the benefit to society quantified in dollars and the costs to society quantified in dollars over the life of the Design Exception. In general practice the benefit to society is quantified by the reduction in crash cost foreseeable because of the proposed design and the cost due to the implementation of that change such as construction and maintenance costs over the life of the project. The Discount (interest) rate to be utilized in benefit/cost analysis is 4%.

Two acceptable methods for calculating a benefit/cost analysis are:

1. Roadside Safety Analysis Program (RSAP)

This method complements the Roadside Design Guide dated June 2002. When hazards cannot be removed or relocated, designers need to determine if a safety device, such as a guardrail or a crash cushion, is warranted to protect motorists from the roadside obstacle. This method can be used to perform a benefit/cost analysis comparing a safety treatment with the existing or baseline conditions (i.e., the do-nothing option) and/or alternative safety treatments. Based on the input (offsets, traffic, slopes, crash history, traffic accident severity levels, etc.) of information available to the user, the program will offer results which can be used in comparing courses of action.

When utilizing RSAP for analysis, the accident severity level costs should be revised as follows:

Option 3: KABCO

Crash Severity	Comprehensive Crash Cost
Fatal (K)	$6,820,000
Severe Injury (A)	$557,752
Moderate Injury (B)	$111,228
Minor Injury (C)	$67,890
Property Damage Only (O)	$6,500

Source: Florida Department of Transportation Crash Analysis Reporting (C.A.R.) System

2. Historical Crash Method (HCM)

This method can be used for sites with a crash history. It is basically the ratio (benefit/cost) of the estimated reduction in crash costs to the estimated increase in construction and maintenance cost. The annualized conversion will show whether the estimated expenditure of funds for the benefit will exceed the direct cost, thereby lending support as to whether the improvement should be done or not.

The HCM uses the following ***Highway Safety Improvement Program Guideline (HSIPG)*** cost per crash by facility type to estimate benefit to society while the cost to society is estimated by the cost of right of way, construction, and maintenance.

HSIPG COST/CRASH BY FACILITY TYPE						
FACILITY TYPE	DIVIDED			UNDIVIDED		
	URBAN	SUBURBAN	RURAL	URBAN	SUBURBAN	RURAL
2-3 Lanes	$98,837	$150,613	$262,821	$114,040	$222,040	$416,658
4-5 Lanes	$110,115	$183,372	$369,954	$87,390	$158,476	$93,628
6+ Lanes	$109,638	$130,645	$545,271	n/a	n/a	n/a
Interstate	$138,873	n/a	$274,449	n/a	n/a	n/a
Turnpike	$127,584	n/a	$218,394	n/a	n/a	n/a

All State Roads Average Cost/Crash: **$141,085**

The above values were derived from 2007, 2008, 2009, 2010 and 2011 traffic crash and injury severity data for crashes on state roads in Florida using the formulation described in ***FHWA Technical Advisory "Motor Vehicle Accident Costs", T 7570.2, dated October 31, 1994*** and from a memorandum from USDOT, ***Revised Departmental Guidance: Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses, dated February 5, 2008*** updating the value of life saved to $5.8 million, updated from $5.8 million to $6 million on March 18, 2009 and to $6.2 million on July 29, 2011, per the memo posted at: http://www.dot.gov/sites/dot.dev/files/docs/Value_of_Life_Guidance_2011_Update_07-29-2011.pdf**.**

Appendix D

NCHRP 152 Warrant Procedure

other vehicles, and pedestrians. These situational features become extremely important when they do not conform to the driver's expectancies.

For basic definition of roadway geometry and features in outlying or residential areas experience has indicated that lighting intensities of at least 0.6 horizontal footcandles will suffice. For special features, such as pedestrians in dark clothing and unexpected roadway objects, intensities considerably above these basic values appear to be necessary. This is especially true as competition between driving task levels increases.

It is suggested that the lighting intensity levels for residential area classification, as recommended by the new American National Standard Practice for Roadway Lighting, be used as basic lighting levels for the various functional classifications and adjusted based on geometric, operational and environmental complexity instead of area classification. In addition, it is suggested that these levels be adjusted for pavement conditions. These adjustments are discussed later herein.

Warrants

The basic classification scheme discussed previously was based on functional, geometric, operational, and environmental conditions that produce visual information needs and modify the efficiency of visual communications with the driver. This basic scheme has been expanded to include a separate classification for each functional type of facility. In addition, the geometric, operational, and environmental parameters that contribute to the informational needs have been defined (Table 11). A fourth classification, accidents, has also been included. Desirable attributes of roadway lighting systems have also been defined (Table 12).

The research agency staff, consisting of six professionals,

TABLE 11

TRAFFIC FACILITY CHARACTERISTICS PRODUCING OR AFFECTING VISUAL INFORMATION NEEDS

GEOMETRIC	OPERATIONAL	ENVIRONMENTAL
	(a) Noncontrolled-Access Facilities	
Number of lanes Lane width Median openings Curb cuts Curves Grades Sight distance Parking lanes	Signals Left-turn signals and lanes Median width Operating speed Pedestrian traffic	Development Development type Development setback Adjacent lighting Raised-curb medians
	(b) Noncontrolled-Access Intersections	
Number of legs Approach-lane width Channelization Approach sight distance Grades on approach Curvature on approach Parking lanes	Operating speed on approval Type of control Channelization Level of service Pedestrian traffic	Development Deveolpment type Adjacent lighting
	(c) Controlled-Access Facilities	
Number of lanes Lane width Median width Shoulders Slopes Curves Grades Interchanges	Level of service	Development Development setback
	(d) Controlled-Access Interchanges	
Ramp types Channelization Frontage roads Lane width Median width Number of freeway lanes Main-lane curves Grades Sight distance	Level of service	Development Development setback Cross-road lighting Freeway lighting

TABLE 12

DESIRABLE ATTRIBUTES OF ROADWAY LIGHTING SYSTEMS

(*a*) Noncontrolled-Access Facilities
Uniform lighting on pavement surface
Infrequent spacings to reduce glare
High mounting heights to reduce glare
Median location to reduce headlight glare
Median location to light areas adjacent to roadway
Gradual transitions from light to dark areas
Gradual transitions from dark to light areas
(*b*) Controlled-Access Facilities
Uniform lighting on pavement surface
Infrequent spacings to reduce glare
High mounting heights to reduce glare
Median location to reduce headlight glare
Median location to light areas adjacent to roadway
High-mast lighting in interchange areas
Gradual transitions from light to dark areas
Gradual transitions from dark to light areas

assigned weighting factors to each of the parameters. Justification for the weighting factors came from collective judgment, field study results, and the literature (see "Traffic Control and Roadway Elements (*25*)). An unlighted and lighted weighting factor was assigned to each parameter. The difference between the two factors represents the degree of effectiveness provided by fixed lighting.

Tables 13, 14, 15, and 16 represent the final classification scheme for the 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 13) is 85 points. These 85 points represent a facility where all geometric, operational, environmental, and accident parameters have a rating of 3 (number of lanes, 6; median width, 10 to 20 ft; development, 30 to 60 percent; night-to-day accident rate, 1.2 to 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 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 of 85 points or more is, of course, warranted. The degree to which the total warranting points exceed the minimum (85 for continuous arterial lighting) serves as the basis for setting priorities.

Justification for Ratings and Weighting Factors

As previously stated, a professional team rated and assigned weightings to each of the classification factors. Justification for the ratings and weightings came from the field studies, literature, and collective judgment of the professional team. Each member of the professional team was provided a transcript of the field study interviews, questionnaire results, and critique sessions. In addition, each team member received a summary of accident rates for various traffic control and roadway element conditions. This summary was prepared from *Traffic Control and Roadway Elements* (*25*). After each team member had a sufficient opportunity to review this information in detail, eight three-hour work sessions were held to assign the ratings and relative weightings. Each assignment was discussed and researched until a consensus of the five-member team was achieved. The following discussion describes the rationale involved in the ratings and weightings developed by the professional team. The ratings are highly judgmental and experience gained through field application may lead to refinement and changes in the ratings and weightings.

Geometric Factors

Number of Lanes.—As the number of operating lanes increases, the ability of the headlights to effectively light the periphery of the roadway is greatly reduced, especially in inclement weather. Identification of the extremes of the roadway is an important element in driver orientation. Normal headlights are able to illuminate the traveled lane and one lane on either side to an acceptable degree. Therefore, with two lanes in one direction (total of four lanes) the driver should have little difficulty in locating the extremes of the roadway and the condition would be ideal—a rating of 1. Three lanes in one direction would result in the drivers in the inside or outside lane being able to identify only one edge of the roadway—not critical, but certainly not ideal. Thus, a rating of 3 seems appropriate. With four or more lanes in one direction, the orientation of the driver becomes a critical factor and the 5 rating is justified.

Lane Width.—As the effective width of the lane is reduced, the problem of tracking becomes increasingly important to the driver. This results in increased concentration on the steering (positional) task and a reduction of a corresponding amount of time that can be devoted to the other elements of the driving task. Therefore, it is important to provide an environment that minimizes the amount of time required to accomplish the nontracking aspects of driving. A lane width of 13 ft or more presents little difficulty and is, therefore, assigned the ideal rating of 1. A lane width of 9 ft or less is critical, as there is little leeway for tracking errors. A rating of 5 has been assigned to this condition. An 11-ft lane is acceptable for most operations and has been assigned a rating of 3, thus completing the scale of ratings for lane width for all classifications.

Number of Legs.—For at-grade intersections, the complexity of operations increases as the number of approach legs to the intersection increases. Ideally, there would be no intersecting legs (i.e., no intersection). Three intersecting legs, such as a T or Y intersection, would be the smallest number of legs possible to have an intersection. This condition has received a rating of 2. Six or more legs, or traffic circles, represent the most complex condition and

TABLE 13

CLASSIFICATION FOR NONCONTROLLED-ACCESS FACILITY LIGHTING

CLASSIFICATION FACTOR	RATING 1	2	3	4	5	UNLIT WEIGHT (A)	LIGHTED WEIGHT (B)	DIFF. (A-B)	SCORE [RATING X(A-B)]
GEOMETRIC FACTORS									
No. of lanes	4 or less	-	6	-	8 or more	1.0	0.8	0.2	______
Lane Width	>12'	12'	11'	10'	<10'	3.0	2.5	0.5	______
Median Openings per mile	<4.0 or one way operation	4.0-8.0	8.1-12.0	12.0-15.0	>15.0 or no access control	5.0	3.0	2.0	______
Curb Cuts	<10%	10-20%	20-30%	30-40%	>40%	5.0	3.0	2.0	______
Curves	<3.0°	3.1-6.0°	6.1-8.0°	8.1-10.0°	>10°	13.0	5.0	8.0	______
Grades	<3%	3.0-3.9%	4.0-4.9%	5.0-6.9%	7% or more	3.2	2.8	0.4	______
Sight Distance	>700'	500-700'	300-500'	200-300'	<200'	2.0	1.8	0.2	______
Parking	prohibited both sides	loading zones only	off-peak only	permitted one side	permitted both sides	0.2	0.1	0.1	______
						GEOMETRIC TOTAL			======
OPERATIONAL FACTORS									
Signals	all major intersections signalized	substantial majority of intersections signalized	most major intersections signalized	about half the intersections signalized	frequent non-signalized intersections	3.0	2.8	0.2	______
Left turn lane	all major intersections or one way operation	substantial majority of intersections	most major intersections	about half the major intersections	infrequent turn bays or undivided streets	5.0	4.0	1.0	______
Median Width	30'	20-30'	10-20'	4-10'	0-4'	1.0	0.5	0.5	______
Operating Speed	25 or less	30	35	40	45 or greater	1.0	0.2	0.8	______
Pedestrian Traffic at night (peds/mi)	very few or none	0-50	50-100	100-200	>200	1.5	0.5	1.0	______
						OPERATIONAL TOTAL			======
ENVIRONMENTAL FACTORS									
% Development	0	0-30%	30-60%	60-90%	100%	0.5	0.3	0.2	______
Predominant Type Development	undeveloped or backup design	residential	half-residential and/or commercial	industrial or commercial	strip industrial or commercial	0.5	0.3	0.2	______
Setback Distance	>200	150-200'	100-150'	50-100'	<50	0.5	0.3	0.2	______
Advertising or area lighting	none	0-40%	40-60%	60-80%	essentially continuous	3.0	1.0	2.0	______
Raised Curb Median	none	continuous	at all intersections	at signalized intersections	a few locations	1.0	0.5	0.5	______
Crime Rate	extremely low	lower than city aver.	city aver.	higher than city aver.	extremely high	1.0	0.5	0.5	______
						ENVIRONMENTAL TOTAL			======
ACCIDENTS									
Ratio of night to day accident rates	<1.0	1.0-1.2	1.2-1.5	1.5-2.0	2.0*	10.0	2.0	8.0	______
						ACCIDENT TOTAL			======

*Continuous lighting warranted

GEOMETRIC TOTAL = ______

OPERATIONAL TOTAL = ______

ENVIRONMENTAL TOTAL = ______

ACCIDENT TOTAL = ______

SUM = ______ POINTS

WARRANTING CONDITION = 85 points

TABLE 14

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

*Intersection lighting warranted

GEOMETRIC TOTAL = ____

OPERATIONAL TOTAL = ____

ENVIRONMENTAL TOTAL = ____

ACCIDENT TOTAL = ____

SUM = ____ POINTS

WARRANTING CONDITION = 75 points

TABLE 15

CLASSIFICATION FOR CONTROLLED-ACCESS FACILITY (FREEWAY) LIGHTING

CLASSIFICATION FACTOR	RATING 1	2	3	4	5	UNLIT WEIGHT (A)	LIGHTED WEIGHT (B)	DIFF. (A-B)	SCORE [RATING X(A-B)]
GEOMETRIC FACTORS									
No. of Lanes	4		6		≥8	1.0	0.8	0.2	
Lane Width	>12'	12'	11'	10'	≤9'	3.0	2.5	0.5	
Median Width	>40'	24-39'	12-23'	4-11'	0-3'	1.0	0.5	0.5	
Shoulders	10'	8'	6'	4'	0'	1.0	0.5	0.5	
Slopes	≥8:1	6:1	4:1	3:1	2:1	1.0	0.5	0.5	
Curves	0-1/2°	1/2-1°	1-2°	2-3°	3-4°	13.0	5.0	8.0	
Grades	<3%	3-3.9%	4-4.9%	5-6.9%	>7%	3.2	2.8	0.4	
Interchange Freq.	4 mi.	3 mi.	2 mi.	1 mi.	<1 mi.	4.0	1.0	3.0	
						GEOMETRIC TOTAL			
OPERATIONAL FACTORS									
Level of Service (any dark hour)	A	B	C	D	E	6.0	1.0	5.0	
						OPERATIONAL TOTAL			
ENVIRONMENTAL FACTORS									
% Development	0%	25%	50%	75%	100%	3.5	0.5	3.0	
Offset to Develop	200'	150'	100'	50'	<50'	3.5	0.5	3.0	
						ENVIRONMENTAL TOTAL			
ACCIDENTS									
Ratio of night to day accident rates	1.0	1-1.2	1.2-1.5	1.5-2.0	2.0*	10.0	2.0	8.0	
						ACCIDENT TOTAL			

*Continuous lighting warranted

GEOMETRIC TOTAL = ______

OPERATIONAL TOTAL = ______

ENVIRONMENTAL TOTAL = ______

ACCIDENT TOTAL = ______

SUM = ______ POINTS

WARRANTING CONDITION = 95 points

have been given the rating of 5. Uniform distribution has been used to assign ratings of 3 and 4.

Median Openings.—The control of access reduces the probability of accidents occurring between through and turning vehicles. As the number of access points is increased, the possibility of conflict increases; therefore, there is a greater need for lighting. Two-way noncontrolled-access streets with median openings at 1,000-ft or greater intervals, and one-way streets, have nearly ideal operation for this condition and therefore are given a rating of 1. A block spacing of 500 ft (i.e., about ten openings per mile) is considered to be about the minimum condition for acceptable street operation and has been assigned a rating of 3. A spacing of 300 ft or less between openings, or a situation with no separator and two-way operation, results in a low quality of street operation. This condition has been given a rating of 5, as a good view of the vehicle maneuvers ahead is critical to safe and efficient vehicle operation. Also, the observed accident rate increases rather slowly up to 15 openings per mile and a great deal more rapidly thereafter (*25*).

Curb Cuts.—The number and length of curb cuts determine the number of vehicle maneuver points available and the degree of operational complexity on noncontrolled-access streets. Less than 10 percent curb openings will not substantially impair traffic operation; therefore, an ideal rating of 1 seems appropriate. When curb openings approach 50 percent, the complexity of operation is critical;

TABLE 16

CLASSIFICATION FOR INTERCHANGE LIGHTING

CLASSIFICATION FACTOR	RATING 1	2	3	4	5	UNLIT WEIGHT (A)	LIGHTED WEIGHT (B)	DIFF. (A-B)	SCORE [RATING X(A-B)]
GEOMETRIC FACTORS									
Ramp Types	Direct	Diamond	Button Hooks Cloverleafs	Trumpet	Scissors and Left-side	2.0	1.0	1.0	____
Cross-Road Channelization	none		continuous		at interchange intersections	2.0	1.0	1.0	____
Frontage Roads	none		one-way		two-way	1.5	1.0	0.5	____
Freeway Lane Widths	>12	12	11	10	<10	3.0	2.5	0.5	____
Freeway Median Widths	>40	34-40	12-24	4-12	<4	1.0	0.5	0.5	____
No Freeway Lanes	4 or less		6		8 or more	1.0	0.8	0.2	____
Main Lane Curves	<1/2°	1-2°	2-3°	3-4°	>4°	13.0	5.0	8.0	____
Grades	3%	3-3.9%	4-4.9%	5.6.9%	7% or more	3.2	2.8	0.4	____
Sight Dist. Cross Road Intersection	>1000'	700-1000'	500-700'	400-500'	<400'	2.0	1.8	0.2	____
						GEOMETRIC TOTAL			____
OPERATIONAL FACTORS									
Level of Service (any dark hour)	A	B	C	D	E	6.0	1.0	5.0	____
						OPERATIONAL TOTAL			____
ENVIRONMENTAL FACTORS									
% Development	none	1 quad	2 quad	3 quad	4 quad	2.0	0.5	1.5	____
Set-Back Distance	>200'	150-200'	100-150'	50-100'	<50'	0.5	0.3	0.2	____
Cross-Road Approach Lighting	none		partial		complete	3.0	2.0	1.0	____
Freeway Lighting	none		interchanges only		continuous*	5.0	3.0	2.0	____
						ENVIRONMENTAL TOTAL			____
ACCIDENTS									
Rate of night to day accident rates	<1.0	1.0-1.2	1.2-1.5	1.5-2.0	>2.0*	10.0	2.0	8.0	____
						ACCIDENT TOTAL			____

*Complete lighting warranted

GEOMETRIC TOTAL = ____

OPERATIONAL TOTAL = ____

ENVIRONMENTAL TOTAL = ____

ACCIDENT TOTAL = ____

SUM = ____ POINTS

COMPLETE LIGHTING WARRANTING CONDITION = 90 points

PARTIAL LIGHTING WARRANTING CONDITION = 60 points

thus, the rating of 5 is assigned. For the interval between 1 and 5, the percentage of curb openings has been uniformly distributed.

Curves.—The degree of difficulty in negotiating horizontal curves is probably best indicated by accident experience. Curves with curvature in excess of 10° for non-controlled-access streets and 4° for controlled-access facilities have apparent accident rates four to five times those with lesser curvature (*25*). Thus, curves of 10° and 4°, respectively, have been selected as the upper limit of scale and assigned a value of 5. Curves up to 3° for non-controlled-access facilities and ½° for controlled-access facilities have a minimum accident rate. The intermediate ratings have been distributed in general accord with the apparent exponential accident rate with increasing curve severity.

Grades.—The relationship between grade and driving complexity is difficult to establish. The interaction of grade and curvature seems to indicate a linear relation with increasing grades. Below 3° there is little effect of grade and a rating of 1 is appropriate. At more than 7 percent, the effect of grade is very pronounced and the effect is still appreciable on grades of more than 5 percent. Thus, 5 percent was established as the upper bound of the minimum value and is assigned a rating of 3. The remaining gaps were distributed uniformly.

Sight Distance.—The operating speeds on arterial streets and the expected occurrence of conflicts reduce the need for extended sight distance. A sight distance of less than 200 ft would certainly be critical; greater than 700 ft would undoubtedly provide greater information than the driver could effectively use. These two extremes were assigned ratings of 1 and 5, respectively, and the ranges between these extremes have been distributed in a uniform manner. For controlled-access conditions, where higher speeds and less frequent expected conflicts exist, a sight distance of 400 ft has been assigned the critical rating, with 1,000 ft as the ideal. These two extremes were assigned ratings of 1 and 5, respectively, and the ranges between these extremes have been distributed in a uniform manner.

Channelization.—From a geometric standpoint, channelization at intersections and cross-road channelization at interchanges introduces visual task problems for the driver. The less frequent the channelization, the fewer visual task problems will be encountered. Thus, intersections with no channelization have been given the ideal rating of 1, whereas complete channelization on all approaches has been given the rating of 5. Uniform distribution has been used for the ranges between. For cross roads at interchanges, the intersections without channelization have been rated at 1. Continuous channelization of the crossroad has been given the middle rating of 3. Channelization at the interchange intersections only has been rated at 5. This was done to account for the unexpected occurrence of channelization after driving in an area with no channelization.

Median Width.—Median width has been included from the geometric standpoint on controlled-access facilities to describe the level of comfort associated with opposing vehicle separation. A separation of 40 ft or more is sufficient to eliminate interaction between opopsing vehicles and has been assigned the rating of 1. Median widths of less than 4 ft represent the most undesirable condition, rated at 5. Relative uniform distribution has been used for the ranges between.

Parking.—The effect of parking on the need for lighting is directly related to the parking condition on the facility. Five basic conditions were identified and assigned to the rating scale, as follows:

PARKING CONDITION	RATING
Prohibited both sides	1
Loading zones only	2
Off-peak parking permitted	3
Parking permitted, one side	4
Parking permitted, both sides	5

Shoulders.—Although parking is prohibited on controlled-access facilities, there often are emergency situations where vehicles must take refuge adjacent to the through traffic lanes. For this reason shoulders or other areas of refuge are important. The absolute minimum shoulder width that can accommodate a stopped vehicle is approximately 6 ft, and this value has been given the rating of 3. An ideal situation would be 10 ft, assigned the rating of 1. The absence of shoulders represents an absolute critical condition, assigned the value of 5.

Slopes.—For the high-speed operation of controlled-access facilities, it is desirable to provide gentle slopes for errant vehicles. Slopes of 4:1 have been generally accepted as the desirable minimum and thus have been assigned the rating of 3. Slopes of 2:1 have been accepted as the absolute maximum, assigned the value of 5. The ideal rating of 1 has been given to slopes of 8:1 or greater, the current accepted desirable slope.

Interchanges.—Interchange frequency has been included in geometric conditions for controlled-access facilities to represent the geometric design problems that usually result when interchange spacings are close. It is desirable to have at least two miles between interchanges to develop acceleration and deceleration lanes and gentle vertical profiles. This spacing has been rated 3. Any spacing closer than one mile does not provide adequate distance for good geometric development. Thus, spacings closer than one mile have been assigned the rating of 5. The ideal rating of 1 has been assigned to spacings of four miles on an arbitrary basis, but considering that this spacing is possible only in rural areas.

Ramp Types.—This category is included to represent the complexity of various ramp types. The most difficult of all ramp types to negotiate are the scissors and left-side exits. These have been rated at 5. The next most difficult are the trumpet ramps, rated at 4. Button-hook ramps and cloverleafs have been rated at 3, and diamond connections at 2. Direct connections have been given the 1 rating.

Frontage Roads.—The presence or absence of frontage roads on controlled-access facilities determines to a large extent the geometric design of ramps and the extent of activity adjacent to the facility. Two-way frontage roads are the most complex and have been rated at 5. Freeways without frontage roads preclude the problem and thus are rated at 1. One-way frontage roads have been rated at 3.

Operational Factors

Signals.—The presence or absence of traffic signals at major intersections is a major determinant in the need for external illumination. The lack of target value of signs increases the need for identification of the intersection area as well as decreasing the degree of difficulty of the tracking task, thus permitting greater concentration on the operational situation. The descriptors represent the broad spectrum of conditions that exist on noncontrolled-access facilities.

Left-Turn Lane and Signal.—The presence or absence of a left-turn lane and protected signal phase are important contributors to smooth and efficient operation. When these facilities are not provided, the identification of turning vehicles becomes a critical part of the night driving environment. Again, lighting can do little to correct the basic problem except to reduce the complexity of the driving task on the approaches to the critical intersection. As the frequency of these critical intersections increases, the need also increases for a reduction in driving task difficulty to provide more time for concentration on other elements of the task. The descriptor reflects this need.

Median Width.—An increase in the width of the median increases operational efficiency on noncontrolled-access facilities by reducing the effects of opposing headlights and providing an area to "shadow" turning and crossing vehicles. The critical dimension for turning vehicles is 10 ft; for crossing vehicles, 20 ft. Thus, for a median width of 30 ft or more, few serious operational problems exist, and a rating of 1 has been assigned to this condition. A median less than 4 ft in width would provide no space to "shadow" vehicles and, accordingly, has been assigned a rating of 5. Widths in the range of 10 to 20 ft provide space to shadow turning vehicles but not crossing vehicles, a condition considered to be a minimum in this analysis. The remaining ratings were assigned values in accordance with these two conditions. Median width has also been rated for controlled-access facilities based on reduction of headlight glare. A median width of 3 ft would provide for an average lateral displacement between drivers of 10 ft, the most critical separation from an opposing glare standpoint. This width has been assigned the rating of 5. Median width of 12 to 23 ft represents a lateral separation determined as the borderline between comfort and discomfort, and thus has been assigned the value rating of 3. A median width of 40 ft provides for no discomfort from opposing headlights and has been assigned the rating of 1.

Operating Speed.—The speed of operation on noncontrolled-access street systems is a primary determinant in evaluating the need for lighting. Most modern headlights will provide sight distance for safe operation up to 40 mph. Certainly, operating speeds in excess of this must be considered critical, as the use of high beams would be substantially restricted by the interference with opposing vehicles. A speed slightly below the critical value, say 35 mph, should be considered a minimum to provide some margin for error. Below 25 mph, the headlights should provide sufficient advance warning. The speed range for 25 through 45 mph was allocated to the five ratings in 5-mph increments.

Pedestrian Traffic at Night.—An increase in the number of pedestrians crossing the roadway during the hours of darkness increases the relative hazard of driving on the facility. Two hundred crossings per night appeared to be sufficient to justify a rating of 5; no pedestrians would be the ideal condition of 1. The intermediate values were uniformly distributed between these two extremes.

Channelization.—The type of channelization and signal control at an intersection determines the smoothness of operation within the intersection. Five descriptors have been developed to represent this operation. Left- and right-turn lanes with signal control have been rated at 1. No channelization or control received the rating of 5. The remaining descriptors were assigned to the intermediate values.

Level of Service.—Level of service is a method of describing operations on controlled-access facilities and intersections. Level of service may range from A to F, with A representing ideal conditions. This level has been assigned the rating of 1. Levels of service E and F represent critical operations and, thus, have been assigned the value of 5. The intermediate ratings were assigned to levels of service B, C, and D.

Environmental Factors

Percent Developed Frontage—For noncontrolled-access facilities, the percentage of the roadside that is developed affects the number and frequency of vehicle maneuver points. The location of service drives and the identification of vehicles entering or leaving the roadway are factors of considerable importance in the driving task. As the percentage of development increases, the need for additional lighting also increases. The range from 0 to 100 percent development has been distributed over the rating range by subjective judgment. The value of 60 percent as the upper bound of the minimum condition (rating of 3) seems reasonable.

For controlled-access facilities the ratings are basically the same, with the exception of interchange areas. For interchanges the team elected to describe the percent development in terms of the number of quadrants in the interchange that are developed. The rating of 1 has been assigned to the condition of no development and the rating of 5 to all four quadrants developed. Uniform assignment has been made to the remaining ratings.

Predominant Development.—The type of development that most nearly is compatible with noncontrolled-access street operation is undeveloped or backup-type residential development, assigned a rating of 1. The type least compatible with good operation is strip commercial or industrial development, assigned a rating of 5. The other descriptors represent the various levels between these two extremes.

Setback Distance.—The setback distance to the development also affects the type of operation and the degree of interference from the development. For setback distances of 50 ft or less, the operation of vehicles on adjacent property will be essentially parallel to the traffic stream; thus, identification of potentially conflicting vehicles is considerably more difficult. With increasing setback distances, the degree of control of the vehicle entering and leaving the parking area is increased. For setbacks greater than 200 ft, control of access to and from the adjacent areas is complete. The rating of this factor was uniformly distributed between these two extremes.

Advertising or Area Lighting.—When large segments of the roadside are lighted, the roadway can become the darkest portion of the driving environment. This factor must be included in the warranting conditions. When 40 percent or less of the roadside is lighted, the problem will not be critical; when roadside lighting goes beyond 60 percent the problem is drastically increased. The variation from no roadside lighting to continuous roadside lighting can produce serious visual problems in driving. This range has been subjectively rated from 1 to 5.

Raised-Curb Median.—Raised-curb medians have been included as an environmental factor because of the serious interaction between environmental lighting and the transition to the median section. The frequency of these transition problems is represented in the 1 to 5 ratings.

Other Fixed Lighting.—Cross-road approach lighting and freeway lighting have been included in environmental factors for interchanges. It appears reasonable that continuous lighting on cross-roadways or the freeway should contribute to warranting lighting of the interchange. Thus, these conditions have the rating of 5. No lighting of the cross-roadway and freeway has been rated as 1, with partial lighting rated at 3.

Crime Rate.—Reduction in crime rate is one of the often mentioned benefits of fixed roadway lighting on surface streets in downtown urban areas. It appeared desirable, therefore, to include crime rate as a warranting condition. A crime rate equal to the city average has been given the 3 rating. The continuum from 1 to 5 has been rated in relation to the city average. It is suggested that the police department be asked to rate a given facility on this basis for use by the lighting designer.

Accidents

The ratio of night-to-day accident rates has been a traditional measure of the need for roadway lighting. Accident experience should be weighted heavily in any warranting scheme. The ideal condition would be a ratio of 1:1; that is, the total accident rate at night is the same as the total accident rate under daylight conditions. Under normal conditions a ratio of 1.5:1 is not unusual and has, therefore, been assigned a rating of 3. A ratio of 2:1 or more is critical, and lighting should be considered as being warranted for this site. Other ratios have been uniformly assigned to the ratings. Accident rate should include all types and severity of accidents and be expressed in terms of accidents per million vehicle-miles.

Weighting of Factors

The professional research team was used to establish weighting factors for each of the classification elements for lighted and unlighted conditions. Decisions were based on the compilation of accident rate data presented in *Traffic Control and Roadway Elements—Their Relationship to Highway Safety/Revised* (*25*). Where data were not available, the team used a combination of collective judgment and the relative importance of other factors for which data were available.

Priorities

It was previously stated that 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) represents the effectiveness that can be achieved through the provision of fixed lighting. Thus, a generalized model for setting priorities would be

$$PI = \frac{W \times ADT_N}{C} \tag{2}$$

in which

PI = priority index;
W = warranting number for a given facility;
ADT_N = night average daily traffic; and
C = cost of the lighting improvement.

This generalized model is developed more fully in the later section on "Cost-Effectiveness."

DESIGN GUIDELINES FOR FIXED LIGHTING

This phase of the research dealt with a detailed review of the current (and proposed) guidelines and practices, and comparison of these guidelines with the needs of the visual environment determined in this research. Specifically, this comparison is made with the "American National Standard Practice for Roadway Lighting" (*13*) and AASHTO's *An Informational Guide for Roadway Lighting* (*10*).

Many effective changes have been made in the latest (1971) revision of the American National Standard Practice for Roadway Lighting as compared to the 1963 edition. In the design section, a concise "design process," or an outline of the steps in lighting design, that should prove helpful to the designer, has been included. However, there is some concern that the design section may be overshadowed by the technical information on luminaire distribution and roadway classification presented prior to the design process. These should be supplemental and thus presented following the design process.

The first step in the design process is:

> Determination from roadway classification and adjacent land use (area classification) of the quantity of light desired, in average horizontal footcandles.

This "step" is supplemented with basically the same suggestions as contained in the 1963 edition, as follows:

> It is important that roadway lighting be planned on the basis of traffic information, which includes the factors necessary to provide traffic safety and pedestrian security. Some of the factors applicable to the specific problem which are to be carefully evaluated are:
>
> A. Type of land-use development (area classification) abutting the roadway or walkway.
> B. Type of route (roadway or walkway classification).
> C. Traffic accident experience.
> D. Street crime experience and security.
> E. Roadway construction features:
> 1. Width of pavement or number of traffic lanes.
> 2. Character of pavement surface.
> 3. Grades and curves.
> 4. Location and width of curbs, sidewalks, and shoulders.
> 5. Type and location of very high-volume driveways.
> 6. Width and location of dividing and safety islands with channelizing curbs.