Lighting Justification Report

State Road 40 PD&E Study
From Breakaway Trail to Williamson Boulevard

Financial Management No. 428947-1-22-01

Volusia County, Florida

April 19, 2013

Prepared For:
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Professional Engineer Certificate

I hereby certify that I am a registered professional engineer in the State of Florida practicing with Kittelson & Associates, Inc., a corporation authorized to operate as an engineering business, FEID No. 93-0964447, by the State of Florida, Department of Professional Regulation, and Board of Professional Engineers. I have reviewed or approved the evaluation, findings, opinions and conclusions as reported in this Lighting Justification Report.

The Lighting Justification Report includes an analysis and summary of roadway lighting requirements associated with the S.R. 40 PD&E Study from Breakaway Trail to Williamson Boulevard. I acknowledge that the procedures and references used to develop the results contained in this report are standard to the professional practice of civil engineering as applied through design standards and criteria set forth by the federal, state, and local regulatory agencies as well as professional judgment and experience.

Signature: John R. Freeman Jr

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MEMORANDUM

Date: April 19, 2013 Project #: 11508

To: Mary McGehee
FDOT District 5

From: Jack Freeman, P.E., PTOE & Joey Bansen, P.E.
Project: SR 40 – Breakaway Trail to Williamson Boulevard PD&E Study
(Financial Project No. 428947-1-22-01)
Subject: Lighting Justification Report

This memorandum provides a lighting warrant analysis for the 4-lane to 6-lane widening of State Road 40 (SR 40) from Breakaway Trail to Williamson Boulevard in Volusia County. SR 40 does not currently have roadway lighting on either side of the road or at intersections along the majority of the corridor. The exception is the segment between the I-95 Southbound ramps intersection and Williamson Boulevard, where cobra-head style lighting is provided on utility poles on the north side of SR 40. The I-95/SR 40 interchange is lit with high-mast freeway lighting.

The warrant analysis was conducted per the Florida Department of Transportation (FDOT) *Manual on Uniform Traffic Studies (MUTS)*(Reference 1), *Chapter 15 Highway Lighting Justification Procedure*, which specifies the use of the American Association of State Highway and Transportation Officials (AASHTO) warrants for roadway lighting outlined in the *Roadway Lighting Design Guide.* In addition, *NCHRP Report 152, Warrants for Highway Lighting* (Reference 2) is used by FDOT as a supplement to AASHTO warrants on arterial roadways. The procedure provided in this report was used to determine if lighting is warranted for SR 40 along the study section of roadway.

The warrants provide a basis for roadway conditions under which lighting may be considered warranted and do not necessarily describe the sites where lighting is specifically justified. If the warrants are met, Section 15.3 of the MUTS specifies that a benefit-cost analysis should be performed.

FDOT GUIDANCE

The MUTS Chapter 15 *Highway Lighting Justification Procedure* is currently being updated. Recent FDOT guidance being incorporated into the Chapter 15 update is that intersection lighting should be

provided at all signalized intersections where pedestrian signals with crosswalks are provided. This new FDOT guidance was used for this project.

AASHTO ROADWAY LIGHTING DESIGN GUIDE

The warranting conditions set forth in Section 3.2 of the AASHTO *Roadway Lighting Design Guide* (Reference 3) are for use on freeway sections, but may be applied to roadways other than freeways, as practicable. Section 3.4 (Page 23) of the AASHTO Guide provides general discussion on the application of lighting on non-freeway facilities, stating:

> *Lighting may be provided for all major arterials in urbanized areas and for locations or sections of streets and highways where the ratio of night to day crash rates is higher than the statewide average for similar locations, and a study indicates that lighting would significantly reduce the nighttime crash rate.*

No source for statewide averages of the night to day crash rate ratio could be identified as part of this study. Thus, the night to day crash rate ratios for the roadway segments and intersections within the SR 40 study area were calculated and evaluated in isolation.

Warrant Analysis

A review of the night/day crash rate ratio was performed for the study area of SR 40 based on the above AASHTO guidance. Crash rates are the number of crashes occurring per unit of traffic occurring on the roadway segment or intersection. Crash rates on roadway segments are typically presented as crashes per million vehicle-miles traveled (MVM), and crash rates at intersections are presented as the number of crashes per million entering vehicles (MEV). The night/day crash rate ratio compares the proportion of crashes occurring during the nighttime compared to the daytime by normalizing the crash rates based on the proportion of traffic happening during each of those periods.

Historical crash data for five years between 2007 and 2011 was obtained from FDOT and summarized. The historical crash data for the SR 40 study area was broken into three analysis segments as follows:

- Breakaway Trail to Tymber Creek Road
    - Includes intersection crashes at Breakaway Trail and Tymber Creek Road
- Tymber Creek Road to I-95 Southbound Ramp Intersection
    - Excludes intersection crashes at Tymber Creek Road and I-95 Southbound Ramp Intersection
- I-95 Southbound Ramp Intersection to Williamson Boulevard
    - Includes intersection crashes at I-95 Southbound Ramp Intersection and Williamson Boulevard

The I-95/SR 40 interchange is lit by high-mast interchange lighting, and cobra-style luminaires are provided on the utility poles on the north side of SR 40 between I-95 and Williamson Boulevard. Thus, the analysis broke the historical crashes between the currently unlit and lit segments of SR 40. Table 1 summarizes the night and daytime crashes for each segment and the corridor as a whole, as well as the night/day crash ratio for each.

The crash rate ratios were also broken down by the individual intersections and segments to identify where any specific issues may be.

Crash rates were calculated based on the existing (2011) traffic volumes on the roadway segments or intersections, as presented in the *Design Traffic Technical Memorandum* (DTTM) prepared for this PD&E study (Reference 4). Nighttime and daytime rates were determined by reviewing the 24-hour traffic counts at four locations along the corridor and calculating an average percentage of traffic that occurs during nighttime and dawn/dusk conditions. The counts were taken in January 2011, and sunrise/sunset tables were consulted to determine that twilight hours were from 5:55 pm to 7:15 am. The average percentage of traffic that occurred during this time period was summed and found to be approximately 23%.

Table 1 SR 40 Night/Day Crash Rate Ratios (2007 through 2011)

Segment/Intersection	Type	Length (mi.)	Existing AADT (2011)	MEV/MVM	%ADTn	# Total Crashes	# Nighttime crashes	Nighttime Crash Rate Unlighted	Daytime Crash Rate	Night/ Day Crash Rate Ratio
Breakaway Trail to Tymber Creek	Segment	1.00	11,800	4.3	23%	33	8	1.615	1.508	1.071
Tymber Creek Rd to I-95 SB Ramp	Segment	0.79	23,400	6.7	23%	31	11	1.418	0.770	1.841
I-95 SB Ramp to Williamson Blvd	Segment	0.32	29,700	3.5	23%	97	40	9.965	4.241	2.349
Overall Corridor	**Segment**	**2.11**	**18,900**	**14.6**	**23%**	**161**	**59**	**3.525**	**1.820**	**1.936**
Breakaway Trail Intersection	Intersection		12,340	4.5	23%	6	3	0.579	0.173	3.348
Breakaway Trail to Tymber Creek	Segment	1.00	11,800	4.3	23%	7	2	0.404	0.302	1.339
Tymber Creek Rd Intersection	Intersection		28,900	10.5	23%	20	3	0.247	0.419	0.591
Tymber Creek Rd to Booth Rd	Segment	0.53	23,400	4.5	23%	9	3	0.576	0.344	1.674
Booth Road Intersection	Intersection		29,500	10.8	23%	6	1	0.081	0.121	0.670
Booth Rd to I-95 SB Ramp	Segment	0.26	23,800	2.3	23%	16	7	2.695	1.035	2.604
I-95 SB Ramp Intersection	Intersection		26,700	9.7	23%	25	12	1.071	0.346	3.090
I-95 NB Ramp Intersection	Intersection		28,900	10.5	23%	27	15	1.237	0.295	4.185
I-95 NB Ramp to Williamson Blvd	Segment	0.32	29,700	3.5	23%	3	0	0.000	0.223	0.000
Williamson Blvd Intersection	Intersection		42,350	15.5	23%	42	13	0.731	0.487	1.501

MEV = Million Entering Vehicles (Intersections); **MVM** = Million Vehicle-Miles (segments); **ADT** = Average Daily Traffic (Existing 2011);
%ADTn = Percent of ADT at night

Table 1 shows that the segments of SR 40 between Tymber Creek Road and I-95 Southbound ramps, and between I-95 Southbound ramps and Williamson Boulevard have night crash rates significantly exceeding the daytime crash rates. The night/day crash rate ratio for SR 40 between Breakaway Trail and Tymber Creek Road is approximately 1.0. The overall study corridor from Breakaway Trail to Williamson Boulevard was found to have a night/day crash rate ratio of 1.936, indicating an overrepresentation of crashes during nighttime conditions.

A closer review of the individual intersections and segments indicate a significantly higher nighttime crash rate over the daytime crash rate in the following locations:

- Breakaway Trail intersection
- Breakaway Trail to Tymber Creek Road segment
- Tymber Creek Road to Booth Road segment
- Booth Road to I-95 SB Ramp segment
- I-95 SB Ramp intersection
- I-95 NB Ramp intersection
- Williamson Boulevard intersection

The two I-95 ramp intersections with SR 40 had by far the highest night/day crash rate ratios. The interchange area currently has high mast freeway lighting, so the lighting conditions may not be a significant contributing factor to the crash ratios. Williamson Boulevard also has existing intersection lighting, indicating that light levels may need to be re-evaluated, or there is not a strong correlation between crash occurrence and lighting conditions.

Because no statewide crash rate data is available, a conclusive comparison cannot be made to determine if the AASHTO warrants are met.

NCHRP REPORT 152

Because the AASHTO warrants presented above are not specifically for arterial facilities, the warrants contained in *NCHRP Report 152* were also used as a supplement to evaluate the potential need for roadway lighting on the SR 40 corridor. The procedure and analysis used for the *NCHRP Report 152* warrants is outlined below.

Procedure

NCHRP Report 152 provides a table of warranting conditions based on geometric, operational, and environmental factors, as well as crash history for continuous arterial lighting and arterial intersection lighting (Tables 13 and 14 of document). The tables provide the roadway facility or intersection 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 or greater for the roadway segment, or 75 points for an intersection, lighting is warranted. More detailed discussion of the warrant procedure and criteria in *NCHRP Report 152* is included as Attachment A.

Warrant Analysis

Table 13 Classification for Noncontrolled-Access Facility Lighting in *NCHRP Report 152* was used to determine if lighting is warranted along the study roadway. Each roadway segment between signalized intersections was analyzed individually. The segment from the I-95 NB ramp to Williamson Boulevard was not analyzed because of the short distance and influence from the closely spaced signalized intersections on each end.

In addition to the roadway segments, the six study area signalized intersections were analyzed for lighting warrants using *Table 14 Classification for Intersection Lighting* in *NCHRP Report 152*.

Roadway Segment Warrants

Table 2 provides the results of the lighting warrant analysis. The minimum warranting condition for continuous arterial lighting is 85 points. Several assumptions were made toward the future conditions of the roadway after the project is in place, as follows:

- Geometric Factors:
    - The preferred typical sections recommended in the PD&E alternatives analysis were used in the warrants for the segments. Typical section #1 was used from Breakaway Trail to Tymber Creek Road, and typical section #4 was used from Tymber Creek Road to I-95 SB ramps. See Attachment B for the typical sections used in the warrant analysis.
- Operational Factors:
    - Pedestrian traffic at night: Assumed 50-100 pedestrians per mile based on increased development and improvements to pedestrian facilities.
- Environmental Factors:
    - Percent Development: Assumed 60-90% development along corridor based on increased future development.
    - Predominant type of development: Assumed to be residential from Breakaway Trail to Tymber Creek Road, and Half Residential and/or Commercial from Tymber Creek Road to I-95. The future land use maps for the City of Ormond Beach and Volusia County are included in Attachment C.
    - Advertising or area lighting: Assumed to be 0-40% between Breakaway Trail and Tymber Creek Road because of predominantly residential development. Assumed to

be 40-60% between Tymber Creek Road and I-95 because of mix of residential and commercial development.

- Crime Rate: Assumed to be City average for entire corridor.

The night/day crash ratios developed above for the AASHTO warrants were used in the evaluation.

Table 2 Lighting Warrants for Roadway Segments

Roadway Segment	Typical Section 1 – Breakaway Trail to Tymber Creek Rd	Typical Section 4 – Tymber Creek Rd to Booth Rd	Typical Section 4 – Booth Rd to I-95 SB Ramps
Point Total	57.6	70.6	78.6
Warrant Met?	No	No	**Yes***

* Meets warrant due to night/day crash rate ratio >2.0

As shown in Table 2, the warrant for lighting on roadway segments was met for the segment of SR 40 from Booth Road to I-95 SB Ramps only. The other two segments resulted in point totals well below the warrant threshold of 85 points. Warrant worksheets based on Table 13 in *NCHRP Report 152* are included as Attachment D.

Intersection Warrants

Table 3 provides the results of the SR 40 major intersection lighting warrant analysis. The physical and operating conditions for each intersection were based on the lane configurations and operations analysis performed in the DTTM for this PD&E study. The minimum warranting condition for intersection lighting is 75 points. Several assumptions were made toward the roadway's future conditions after the project is in place. These include the future geometry, intersection control, and level-of-service specified in the DTTM. General assumptions are as follows:

- Operational Factors:
  - Pedestrian traffic at night: Assumed 50-100 pedestrians per hour crossing based on increased development and improvements to pedestrian facilities.
  - Level of Service was determined from the design year 2035 operational analysis in the DTTM.
- Environmental Factors:
  - Percent Development: Assumed 60-90% adjacent development at all intersections except the Interchange Boulevard and Tymber Creek Road intersections.
  - Predominant type of development: Assumed to be residential at Breakaway Trail, and Industrial or Commercial at all other intersections.
  - Advertising or area lighting: Assumed to be none at Breakaway Trail and 40-60% at all other intersections.
  - Crime Rate: Assumed to be City average for entire corridor.

The night/day crash ratios developed above for the AASHTO warrants were used in the evaluation.

Table 3 Lighting Warrants for Intersections

Intersection	Breakaway Trail	Tymber Creek Rd	Booth Rd	I-95 SB Ramp	I-95 NB Ramp	Williamson Blvd
Point Total	71.8	47.0	42.5	76.0	77.0	69.8
Warrant Met?	Yes *	No	No	Yes	Yes	No

* Meets warrant due to night/day crash rate ratio >2.0

As shown in Table 3, the warrant for lighting at intersections was met at the following intersections on SR 40:

- Breakaway Trail
- I-95 SB Ramps
- I-95 NB Ramps

Warrants for all other intersections resulted in point totals well below the warrant threshold of 75 points. Warrant worksheets based on Table 14 in *NCHRP Report 152* are included as Attachment E.

HIGHWAY SAFETY MANUAL

In addition to the FDOT MUTS lighting warrant analyses, the *Highway Safety Manual* (HSM) (Reference 5) was consulted to identify quantifiable guidance on the benefits of installing arterial roadway or intersection lighting. Because SR 40 will be a 6-lane facility and the HSM does not currently include 6-lane facilities in the analysis procedures, the predictive method could not be applied to determine expected future crash rates with and without lighting. Rather, Part D of the HSM was used to identify potential safety factors related to highway lighting.

HSM Chapter 13 identifies the crash effects of highway lighting on roadway segments using a Crash Modification Factor (CMF). A CMF quantifies the change in expected average crash frequency at a site caused by implementing a particular treatment. The treatment specified for the CMF is to provide roadway segment highway lighting previously having no lighting. The base condition for this CMF (CMF = 1.0) is the absence of roadway segment lighting. The HSM's Table 13-56 specifies a CMF of 0.72 (standard error of 0.06) for nighttime injury crashes of all crash types. For nighttime non-injury crashes of all types a CMF of 0.83 (standard error of 0.07) is specified. With a confidence interval of the CMF±two times the standard error, this equates to an expected 16-40% reduction in nighttime injury crashes and an expected 3-31% reduction in nighttime non-injury crashes with the provision of lighting on roadway segments.

Similarly, HSM Chapter 14 presents the CMFs applicable to various intersection treatments. An intersection is defined in the HSM as "the general area where two or more roadways join or cross, including the roadway and roadside facilities for traffic movements within the area." The intersection functional area on each approach includes the decision distance, maneuver distance and queue storage

distance. HSM's Table 14-18 presents the CMFs for providing intersection illumination, with the base condition being the absence of intersection illumination. The CMF for nighttime injury crashes of all types is 0.62 (standard error of 0.1). For nighttime non-injury crashes of all types a CMF of 0.58 (standard error of 0.2) is specified. With a confidence interval of the CMF±two times the standard error, this equates to an expected 18-58% reduction in nighttime injury crashes and an expected 2-82% reduction in nighttime non-injury crashes with the provision of intersection lighting.

The CMFs presented in the HSM for roadway segments and intersections demonstrate a potentially significant reduction in night crashes with the implementation of roadway illumination. The information from the HSM can be used to reinforce the warrant analysis presented above, as well as the benefit-cost analysis presented below.

BENEFIT-COST ANALYSIS

The FDOT MUTS *Highway Lighting Justification Procedure* specifies that once warrants are met, a benefit-cost analysis be performed for newly proposed and existing lighting systems to justify the cost of implementing (or retaining) such systems. MUTS Section 15.3 outlines the procedure for the benefit-cost analysis. Benefit-cost analysis was performed for segments along SR 40 that met the NCHRP Report 152 warrants above, including:

- Tymber Creek Road to I-95 SB Ramps segment
- I-95 SB Ramps to Williamson Boulevard

Though the segment of SR 40 from Tymber Creek Road to Booth Road did not specifically meet the NCHRP Report 152 warrant, it was included in the benefit-cost analysis to determine the benefit-cost of applying roadway lighting consistently along the entire segment proposed to be an urban typical section. The overall segment between Tymber Creek Road and I-95 SB ramps experienced a relatively high night/day crash rate ratio, and the intersections along the segment will be lighted. Thus, continuous lighting would provide consistency along the corridor.

The segment between I-95 SB ramps and Williamson Boulevard was included in the benefit-cost analysis because the closely spaced I-95 ramp intersections both met warrants, and the overall segment including the intersections has a night/day crash rate ratio of 2.35, as shown in Table 1 above.

Procedure

The following steps are a summary of the benefit-cost analysis procedure:

1. If the benefit-cost ratio is equal to 1.0 or more, then the lighting is justified for State Safety Office identified high-crash locations. At other locations, the benefit-cost ratio should be 2.0 or greater. The procedure can be used to analyze either an existing or proposed lighting system.

2. For an existing lighting system, the night unlighted crash rate is assumed to be 1.5 times the night lighted rate. This provides an adequate safety factor in the analytical process and assumptions. For a proposed system, the night unlighted crash rate is based on actual crash data collected at the site.
3. If an existing lighting system is being evaluated to determine if it should continue to operate, the cost of the installation is not considered because it is a sunk cost. This recognized that the initial investment in lighting hardware has already been made.
4. The following equations are used in calculating the benefit-cost ratio:
    a. Analysis of New Roadway Lighting Systems:

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

    b. Analysis of Existing Roadway Lighting Systems:

$$\text{Benefit-Cost Ratio for Lighting Retention} = \frac{\text{ADT} \times \%\text{ADTn} \times 365 \times \text{NRU} \times \text{CRF} \times \text{ACC}}{(\text{TMC} + \text{AEC}) \times 1{,}000{,}000}$$

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

Benefit-Cost Analysis

The following outlines the data and assumptions used in calculating the benefit-cost ratio for installing roadway lighting:

- The segments analyzed have not been identified as high crash locations by the State Safety Office, so the benefit-cost threshold is 2.0.
- ADT was determined from the DTTM. Existing 2011 ADT volumes were used to determine the need for lighting on the existing roadway mitigating the existing crash history.
- %ADTn was determined by examining existing 2011 24-hour traffic counts provided in the DTTM for four locations along the SR 40 study area. The counts were taken in January 2011, and sunrise/sunset tables were consulted to determine that twilight hours were from 5:55 pm to 7:15 am. The average percentage of traffic that occurred during this time period was summed and found to be approximately 23%.

- The FDOT Long Range Estimating (LRE) estimate for installing street lighting on the corridor was used for the initial lighting costs. The initial lighting installation cost from LRE is $421,310 per mile for conventional urban street lighting.
- The historical crash data for the two segments was reviewed to identify the nighttime crashes, which were then broken up by severity.
- Crash costs by severity were determined from page 23-10 of the FDOT Plans Preparation Manual (PPM). The crash costs are based on the KABCO severity scale, and the historical data for the project does not differentiate between Injury A, Injury B, or Injury C. Thus, the costs for the three injury crash types were averaged based on historical proportions for each crash severity. The proportions were sourced from Table 10-3 of the *Highway Safety Manual*.
- The crash reduction factor (CRF) was taken from Table 13-56 of the HSM. The HSM presents a Crash Modification Factor (CMF) of 0.8 for all types and severities of nighttime crashes. The CMF is the inverse of CRF (CRF=1-CMF), so the CMF was converted to a CRF of 0.2 and applied in the benefit-cost analysis. The CRF of 0.2 is consistent with that presented for urban mainline roadway segments in Figure 15-1 of the MUTS.

The benefit-cost ratios were calculated for the two segments of S.R. 40. The benefit-cost ratios are as follows:

- Tymber Creek Road to I-95 SB Ramps = 9.8
- I-95 SB Ramps to Williamson Boulevard = 31.4

Both segments exceed the benefit-cost threshold of 2.0. The segment of SR 40 from I-95 SB Ramps to Williamson Boulevard already has lighting, so a review of the lighting levels could be done to determine if improvements are needed. Benefit-Cost worksheets for the analysis provided above are provided in Attachment F.

CONCLUSIONS AND RECOMMENDATIONS

The following is a summary and conclusions of the lighting justification procedure performed above:

- AASHTO Lighting Warrants:
    - The following individual intersections and segments indicates a significantly higher nighttime crash rate over the daytime crash rate:
        - Breakaway Trail intersection
        - Breakaway Trail to Tymber Creek Road segment
        - Tymber Creek Road to Booth Road segment
        - Booth Road to I-95 SB Ramp segment

- I-95 SB Ramp intersection
- I-95 NB Ramp intersection
- Williamson Boulevard intersection

- The two I-95 ramp intersections with SR 40 had by far the highest night/day crash rate ratios. The I-95 interchange area currently has high mast freeway lighting, so the lighting conditions may not be a significant contributing factor to the crash ratios. Williamson Boulevard also has existing intersection lighting, indicating that light levels may need to be re-evaluated, or there is not a strong correlation between crash occurrence and lighting conditions.
- The SR 40 study corridor as a whole has a high night/day crash rate ratio.
- The AASHTO lighting warrants are typically meant for freeway lighting, but may be applied to other roadways. Additionally, no statewide crash rate data was available, so a conclusive comparison was not made to determine if the AASHTO warrants are met.

- *NCHRP Report 152* Lighting Warrants:
  - The following individual roadway segments and intersections on the SR 40 study corridor meet the *NCHRP Report 152* warrants for roadway lighting:
    - Breakaway Trail intersection
    - Booth Road to I-95 SB Ramps segment
    - I-95 SB Ramps intersection
    - I-95 NB Ramps intersection
- Highway Safety Manual:
  - The HSM contains CMFs for the implementation of roadway and intersection lighting on previously unlit facilities that demonstrate a significant potential for nighttime crash reduction, especially injury crashes.
  - Roadway segments: A 16-40% reduction in nighttime injury crashes and a 3-31% reduction in nighttime non-injury crashes are expected with the provision of lighting on roadway segments.
  - Intersections: An 18-58% reduction in nighttime injury crashes and a 2-82% reduction in nighttime non-injury crashes are expected with the provision of lighting at intersections.
  - The data from the HSM provides additional justification for the installation of lighting at locations experiencing high nighttime crash rates.
- Benefit-Cost Analysis:

- Benefit-cost analysis was performed for the following segments of SR 40, with the results listed below for each:
  - Tymber Creek Road to I-95 SB Ramps: B/C = 9.8
  - I-95 SB Ramps to Williamson Boulevard: B/C = 31.4

- FDOT Guidance:
  - New FDOT guidance is to provide intersection lighting at all signalized intersections providing pedestrian crosswalks.

Recommendations

The following is recommended based on the conclusions of the lighting justification procedure:

1. Provide continuous roadway lighting along the segment of SR 40 from Tymber Creek Road to the I-95 SB ramps.

2. Provide adequate roadway lighting for the segment of SR 40 from I-95 to Williamson Boulevard. A review of the existing lighting is needed to determine if any improvements are needed to meet current illumination standards.

3. Provide intersection lighting at, and in the influence areas of, the signalized intersections along the SR 40 study corridor, which include the following:

   - Breakaway Trail
   - Tymber Creek Road
   - Booth Road
   - I-95 SB Ramps
   - I-95 NB Ramps
   - Williamson Boulevard

REFERENCES

1. Florida Department of Transportation, *Manual on Uniform Traffic Studies,* January 2000.
2. National Cooperative Highway Research Program, *Report 152 Warrants for Highway Lighting,* 1974.
3. American Association of State Highway and Transportation Officials, *Roadway Lighting Design Guide,* October 2005.
4. Final Design Traffic Technical Memorandum for SR 40 PD&E Study, from Cone Road to Williamson Boulevard, Volusia County, FL. Financial Project No. 428947-1-22-01. Prepared for FDOT District 5 by GMB Engineers & Planners, Inc., December 2011. Addendum 1 March 29, 2012.
5. American Association of State Highway and Transportation Officials*, Highway Safety Manual, 1st Edition,* 2010.

ATTACHMENTS

Attachment A NCHRP Report 152 – Warrant Procedure

Attachment B Preferred Typical Sections

Attachment C Future Land Use Maps

Attachment D NCHRP Report 152 - Roadway Segment Warrant Worksheets

Attachment E NCHRP Report 152 - Intersection Warrant Worksheets

Attachment F Benefit-Cost Analysis Worksheets

Attachment A
NCHRP Report 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

$$PI = \frac{W \times ADT_N}{C} \quad (2)$$

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.

Attachment B
Preferred
Typical
Sections

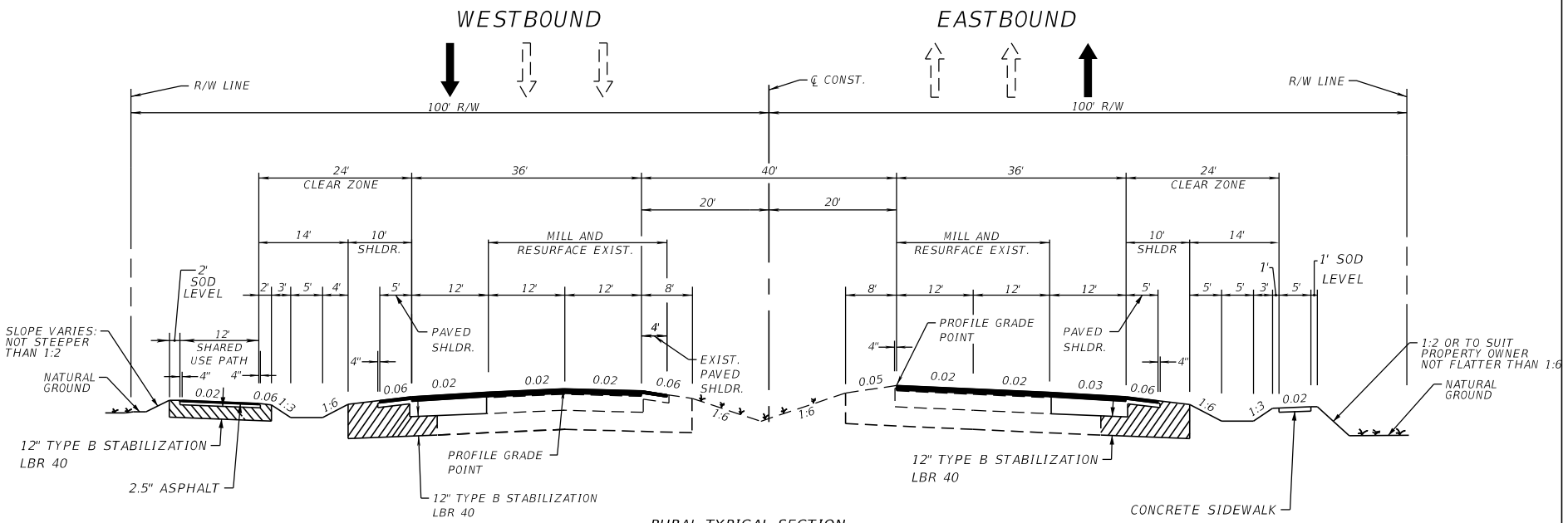
PROJECT IDENTIFICATION

FINANCIAL PROJECT ID 428947-1-22-01 FEDERAL AID PROJECT NO. _____ COUNTY NAME VOLUSIA

SECTION NO. _____ ROAD DESIGNATION SR 40 (GRANADA AVENUE) LIMITS/MILEPOST M.P. 24.5 TO M.P. 26.5

PROJECT DESCRIPTION SR 40 PROJECT DEVELOPMENT & ENVIRONMENTAL STUDY

PROPOSED ROADWAY TYPICAL SECTION



RURAL TYPICAL SECTION
DESIGN SPEED = 65 MPH
POSTED SPEED = 50 MPH (EXISTING)
STA. 1281+60.00 TO STA. 1320+59.00

APPROVED BY: JOHN R. FREEMAN, JR., P.E.	FDOT CONCURRENCE	
Engineer Of Record Signature and Date	Annette K. Brennan, P.E. FDOT District Design Engineer Date	

jbbansen 12/27/2012 8:59:54 PM H:\dgn_projects\SR40\roadway\typsrd_SR40_typicals.dgn

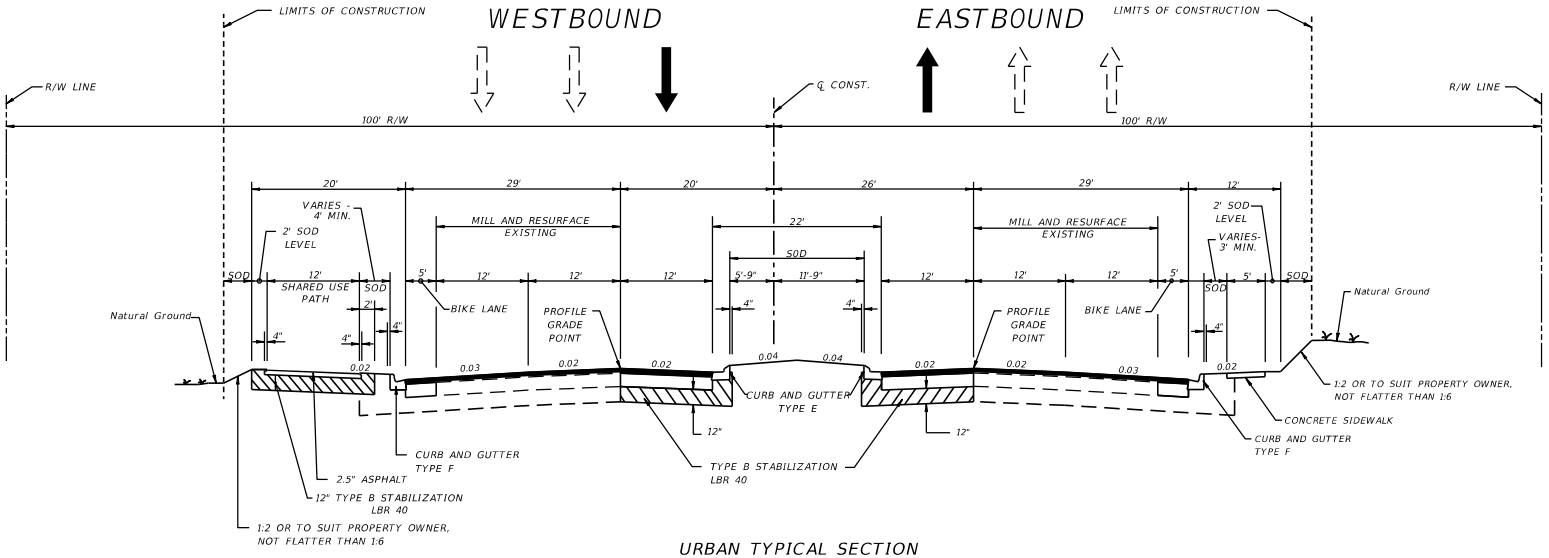
PROJECT IDENTIFICATION

FINANCIAL PROJECT ID 428947-1-22-01 FEDERAL AID PROJECT NO. _____ COUNTY NAME VOLUSIA

SECTION NO. _____ ROAD DESIGNATION SR 40 (GRANADA AVENUE) LIMITS/MILEPOST M.P. 24.5 TO M.P. 26.5

PROJECT DESCRIPTION SR 40 PROJECT DEVELOPMENT & ENVIRONMENTAL STUDY

PROPOSED ROADWAY TYPICAL SECTION



URBAN TYPICAL SECTION
DESIGN SPEED = 45 MPH
POSTED SPEED = 45 MPH
STA. 1340+59.36 TO STA. 1381+56.09

APPROVED BY: JOHN R. FREEMAN, JR., P.E.	FDOT CONCURRENCE	
Engineer Of Record Signature and Date	Annette K. Brennan, P.E. FDOT District Design Engineer Date	

jbbansen 12/27/2012 9:02:14 PM H:\dgn_projects\SR40\roadway\typsrd_SR40_typicals.dgn

Attachment C
Future Land
Use Maps

DENSITY/INTENSITY RESTRICTIONS

PROJECT	LAND USE	ORD. #	RESTRICTION
1. Calvary Church	TC	2007-39	790 AADT
2. 1287 W Granda Blvd	OP	2008-22	900 AADT
3. Marshside	SLDR	2008-54	3.47 UPA
4. River Oaks	SLDR	2008-54	1.74 UPA

FIGURE 1
City of Ormond Beach Future Land Use Map (January 2010)

Legend

- Rural Estate/Agriculture (REA)
- Rural Residential (RR)
- Suburban Low Density Residential (SLDR)
- Low Density Residential (LDR)
- Medium Density Residential (MDR)
- High Density Residential (HDR)
- Office/Professional (O/P)
- Tourist Commercial (TC)
- General Commercial (GC)
- Heavy Commercial (HC)
- Public/Institutional (P/I)
- Activity Center (AC)
- Industrial/Utilities (I/U)
- Recreation/Open Space (R/OS)
- Open Space/Conservation (OS/C)
- Ormond Beach City Limits

YEAR 2025 COMPREHENSIVE PLAN

N
W E
S

1 0.5 0 1 Miles

Prepared By: City of Ormond Beach G.I.S. Department 05/03/2010

Figure 1-11 (North)

Volusia County
FLORIDA

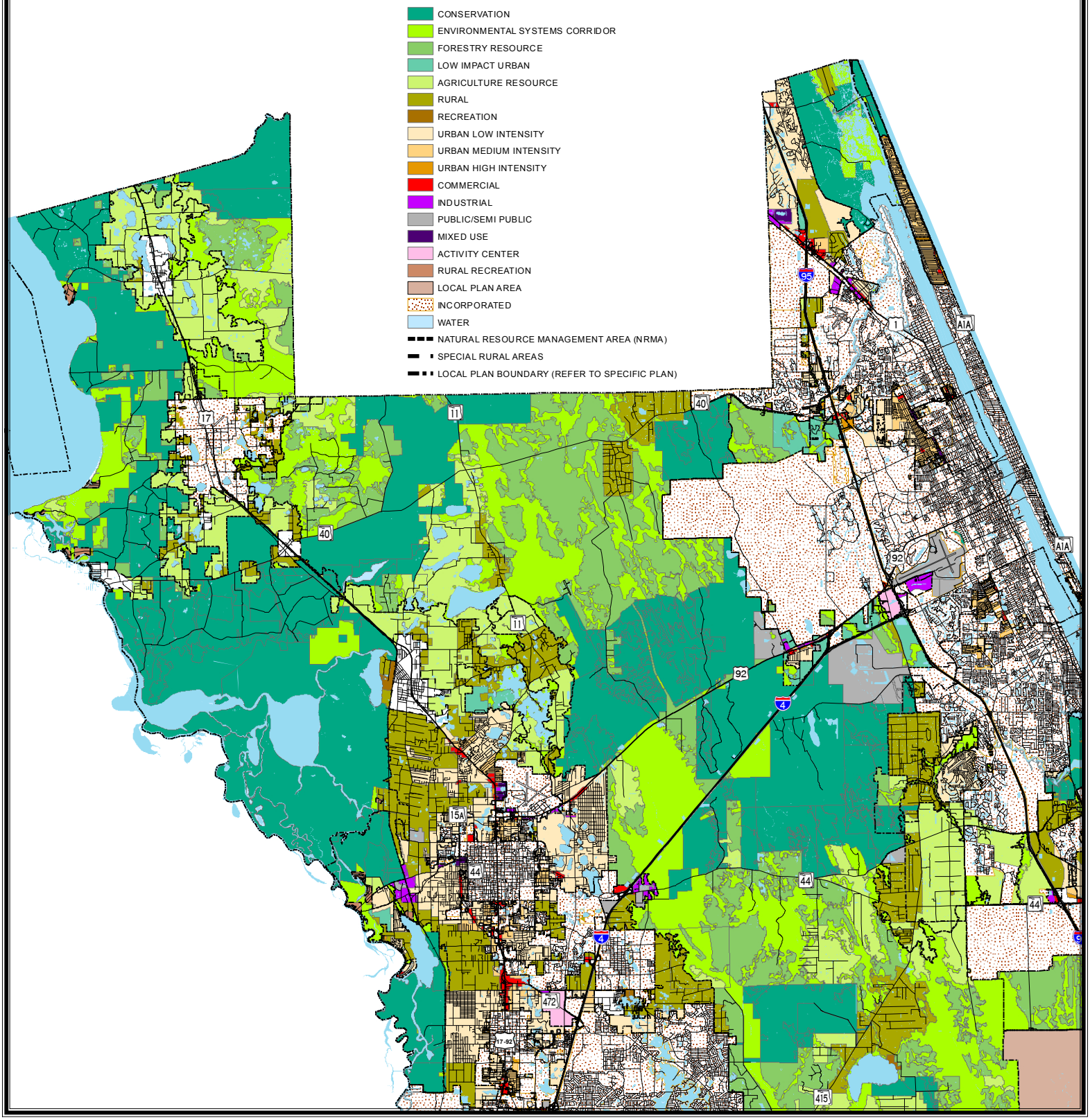
FUTURE LAND USE

PREPARED BY: VOLUSIA COUNTY GROWTH & RESOURCE MANAGEMENT DEPARTMENT

Updated: 23 May 2012

N

1 in = 4.5 miles



Attachment D
NCHRP Report 152 -
Roadway Segment
Warrant Worksheets

NCHRP 152 Lighting Warrants
Classification for Noncontrolled-Access Facility Lighting
From Table 13 - Page 27
Preferred Typical Section 1 - West (Breakaway Trail to Tymber Creek Road)

Classification Factor	Rating 1	2	3	4	5	Given Rating	Diff. (A-B)	Score [Rating X(A-B)]
Geometric Factors								
No. Lanes	4 or less	-	6	-	8 or more	3	0.2	0.6
Lane Width	>12'	12'	11'	10'	<10'	2	0.5	1
Median Openings per mi.	<4.0 or one-way	4.0 - 8.0	8.1 - 12.0	12.0 - 15.0	>15.0 or no control	1	2.0	2
Curb Cuts	<10%	10-20%	20-30%	30-40%	>40%	2	2.0	4
Curves	<3.0 deg.	3.1 - 6.0 deg.	6.1 - 8.0 deg.	8.1 - 10.0 deg.	>10.0 deg.	1	8.0	8
Grades	<3%	3.1 - 3.9%	4.0 - 4.9%	5.0 - 6.9%	7% or more	1	0.4	0.4
Sight Distance	>700'	500-700'	300-500'	200-300'	<200'	1	0.2	0.2
Parking	prohibited both sides	loading zones only	off-peak only	pemitted one side	permitted both sides	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 intersections signalized	frequent non-signalized intersection	3	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	1	1.0	1
Median Width	30'	20 - 30'	10 - 20'	4 - 10'	0 - 4'	1	0.5	0.5
Operating Speed	25 or less	30	35	40	45 or greater	5	0.8	4
Pedestrian Traffic at Night (peds/mi)	very few or none	0-50	50-100	100-200	>200	3	1.0	3
							OPERATIONAL TOTAL	9.1
Environmental Factors								
% Development	0	0 - 30%	30 - 60%	60 - 90%	100%	4	0.2	0.8
Predominant Type Development	undeveloped or backup design	residential	half-residential and/or commercial	industrial or commercial	strip industrial or commercial	3	0.2	0.6
Setback Distance	>200	150 - 200'	100-150'	50 - 100'	<50'	4	0.2	0.8
Advertising or area lighting	none	0 - 40%	40 - 60%	60 - 80%	essentially continuous	2	2.0	4
Raised Curb Median	none	continuous	at all intersections	at signalized intersections	a few locations	1	0.5	0.5
Crime Rate	extremely low	lower than City average	City average	Higher than City average	Extremely high	3	0.5	1.5
							ENVIRONMENTAL TOTAL	8.2
Accidents								
Ratio of night to day accident rates	<1.0	1.0 - 1.2	1.2 - 1.5	1.5 - 2.0	2.0*	3	8.0	24
*Continuous lighting warranted							**ACCIDENT TOTAL**	24
							SUM OF TOTALS =	57.6 **POINTS**
							WARRANTING CONDITION =	85 POINTS
							WARRANT MET?	**NO**

NCHRP 152 Lighting Warrants
Classification for Noncontrolled-Access Facility Lighting
From Table 13 - Page 27
Preferred Typical Section 4 - EAST (Tymber Creek Road to Booth Road)

Classification Factor	Rating 1	2	3	4	5	Given Rating	Diff. (A-B)	Score [Rating X(A-B)]
Geometric Factors								
No. Lanes	4 or less	-	6	-	8 or more	3	0.2	0.6
Lane Width	>12'	12'	11'	10'	<10'	2	0.5	1
Median Openings per mi.	<4.0 or one-way	4.0 - 8.0	8.1 - 12.0	12.0 - 15.0	>15.0 or no control	2	2.0	4
Curb Cuts	<10%	10-20%	20-30%	30-40%	>40%	2	2.0	4
Curves	<3.0 deg.	3.1 - 6.0 deg.	6.1 - 8.0 deg.	8.1 - 10.0 deg.	>10.0 deg.	1	8.0	8
Grades	<3%	3.1 - 3.9%	4.0 - 4.9%	5.0 - 6.9%	7% or more	1	0.4	0.4
Sight Distance	>700'	500-700'	300-500'	200-300'	<200'	1	0.2	0.2
Parking	prohibited both sides	loading zones only	off-peak only	pemitted one side	permitted both sides	1	0.1	0.1
							GEOMETRIC TOTAL	18.3
Operational Factors								
Signals	All major intersections signalized	substantial majority of intersections signalized	most major intersections signalized	about half the intersections signalized	frequent non-signalized intersection	3	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	1	1.0	1
Median Width	30'	20 - 30'	10 - 20'	4 - 10'	0 - 4'	2	0.5	1
Operating Speed	25 or less	30	35	40	45 or greater	5	0.8	4
Pedestrian Traffic at Night (peds/mi)	very few or none	0-50	50-100	100-200	>200	3	1.0	3
							OPERATIONAL TOTAL	9.6
Environmental Factors								
% Development	0	0 - 30%	30 - 60%	60 - 90%	100%	4	0.2	0.8
Predominant Type Development	undeveloped or backup design	residential	half-residential and/or commercial	industrial or commercial	strip industrial or commercial	3	0.2	0.6
Setback Distance	>200	150 - 200'	100-150'	50 - 100'	<50'	4	0.2	0.8
Advertising or area lighting	none	0 - 40%	40 - 60%	60 - 80%	essentially continuous	3	2.0	6
Raised Curb Median	none	continuous	at all intersections	at signalized intersections	a few locations	2	0.5	1
Crime Rate	extremely low	lower than City average	City average	Higher than City average	Extremely high	3	0.5	1.5
							ENVIRONMENTAL TOTAL	10.7
Accidents								
Ratio of night to day accident rates	<1.0	1.0 - 1.2	1.2 - 1.5	1.5 - 2.0	2.0*	4	8.0	32
*Continuous lighting warranted							**ACCIDENT TOTAL**	32
							SUM OF TOTALS =	70.6 **POINTS**
							WARRANTING CONDITION =	85 POINTS
							WARRANT MET?	**NO**

NCHRP 152 Lighting Warrants
Classification for Noncontrolled-Access Facility Lighting
From Table 13 - Page 27
Preferred Typical Section 4 - EAST (Booth Road to I-95 SB Ramps)

Classification Factor	Rating 1	2	3	4	5	Given Rating	Diff. (A-B)	Score [Rating X(A-B)]
Geometric Factors								
No. Lanes	4 or less	-	6	-	8 or more	3	0.2	0.6
Lane Width	>12'	12'	11'	10'	<10'	2	0.5	1
Median Openings per mi.	<4.0 or one-way	4.0 - 8.0	8.1 - 12.0	12.0 - 15.0	>15.0 or no control	2	2.0	4
Curb Cuts	<10%	10-20%	20-30%	30-40%	>40%	2	2.0	4
Curves	<3.0 deg.	3.1 - 6.0 deg.	6.1 - 8.0 deg.	8.1 - 10.0 deg.	>10.0 deg.	1	8.0	8
Grades	<3%	3.1 - 3.9%	4.0 - 4.9%	5.0 - 6.9%	7% or more	1	0.4	0.4
Sight Distance	>700'	500-700'	300-500'	200-300'	<200'	1	0.2	0.2
Parking	prohibited both sides	loading zones only	off-peak only	pemitted one side	permitted both sides	1	0.1	0.1
							GEOMETRIC TOTAL	18.3
Operational Factors								
Signals	All major intersections signalized	substantial majority of intersections signalized	most major intersections signalized	about half the intersections signalized	frequent non-signalized intersection	3	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	1	1.0	1
Median Width	30'	20 - 30'	10 - 20'	4 - 10'	0 - 4'	2	0.5	1
Operating Speed	25 or less	30	35	40	45 or greater	5	0.8	4
Pedestrian Traffic at Night (peds/mi)	very few or none	0-50	50-100	100-200	>200	3	1.0	3
							OPERATIONAL TOTAL	9.6
Environmental Factors								
% Development	0	0 - 30%	30 - 60%	60 - 90%	100%	4	0.2	0.8
Predominant Type Development	undeveloped or backup design	residential	half-residential and/or commercial	industrial or commercial	strip industrial or commercial	3	0.2	0.6
Setback Distance	>200	150 - 200'	100-150'	50 - 100'	<50'	4	0.2	0.8
Advertising or area lighting	none	0 - 40%	40 - 60%	60 - 80%	essentially continuous	3	2.0	6
Raised Curb Median	none	continuous	at all intersections	at signalized intersections	a few locations	2	0.5	1
Crime Rate	extremely low	lower than City average	City average	Higher than City average	Extremely high	3	0.5	1.5
							ENVIRONMENTAL TOTAL	10.7
Accidents								
Ratio of night to day accident rates	<1.0	1.0 - 1.2	1.2 - 1.5	1.5 - 2.0	2.0*	5	8.0	40
*Continuous lighting warranted							**ACCIDENT TOTAL**	40
							SUM OF TOTALS =	**78.6** **POINTS**
							WARRANTING CONDITION =	85 POINTS
							WARRANT MET?	**YES**

Attachment E
NCHRP Report 152 -
Intersection Warrant
Worksheets

NCHRP 152 Lighting Warrants
Classification for Intersection Lighting at SR40 and Breakaway Trail Rd
From Table 14 - Page 28

Classification Factor	Rating 1	2	3	4	5	Given Rating	Diff. (A-B)	Score [Rating X(A-B)]
Geometric Factors								
Number of Legs	-	3	4	5	6 or more	2	0.5	1
Approach lane width	>12'	12'	11'	10'	<10'	2	0.5	1
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	5	1.0	5
Approach Sight Distance	>700'	500 - 700'	300 - 500'	200 - 300'	<200'	1	0.2	0.2
Grades on Approach Streets	<3%	3.1 - 3.9%	4.0 - 4.9%	5.0 - 6.9%	7% or more	1	0.4	0.4
Curvature on Approach Legs	<3.0 deg.	3.0 - 6.0 deg.	6.1 - 8.0 deg.	8.1 - 10.0 deg.	>10.0 deg.	1	8.0	8
Parking in Vicinity	prohibited both sides	loading zones only	off-peak only	permitted one side only	permitted both sides	1	0.1	0.1
							GEOMETRIC TOTAL	15.7
Operational Factors								
Operating Speed on Approach Legs	25 mph or less	30 mph	35 mph	40 mph	45 mph or greater	5	0.8	4
Type of Control	all phases signalized (including turn lane)	left turn lane signal control	through traffic signal control only	4-way stop control	stop control to minor legs or no control	1	0.3	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	1.0	3
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)	2	0.8	1.6
Ped. Volume (peds/hr crossing)	very few or none	0-50	50-100	100-200	>200	3	1.0	3
							OPERATIONAL TOTAL	11.9
Environmental Factors								
% Adjacent Development	0	0 - 30%	30 - 60%	60 - 90%	100%	4	0.2	0.8
Predominant Development near intersection	undeveloped	residential	50% residential - 50% industrial or commercial	industrial or commercial	strip industrial or commercial (no circuitry)	2	0.2	0.4
Lighting in Immediate Vicinity	none	0 - 40%	40 - 60%	60 - 80%	essentially continuous	1	1.5	1.5
Crime Rate	extremely low	lower than City average	City average	Higher than City average	Extremely high	3	0.5	1.5
							ENVIRONMENTAL TOTAL	4.2
Accidents								
Ratio of night to day accident rates	<1.0	1.0 - 1.2	1.2 - 1.5	1.5 - 2.0	2.0*	5	8.0	40
*Continuous lighting warranted							**ACCIDENT TOTAL**	40
							SUM OF TOTALS =	71.8 **POINTS**
							WARRANTING CONDITION =	75 POINTS
							WARRANT MET?	**YES**

NCHRP 152 Lighting Warrants
Classification for Intersection Lighting at SR40 and Tymber Creek Rd
From Table 14 - Page 28

Classification Factor	Rating 1	2	3	4	5	Given Rating	Diff. (A-B)	Score [Rating X(A-B)]
Geometric Factors								
Number of Legs	-	3	4	5	6 or more	3	0.5	1.5
Approach lane width	>12'	12'	11'	10'	<10'	2	0.5	1
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	5	1.0	5
Approach Sight Distance	>700'	500 - 700'	300 - 500'	200 - 300'	<200'	1	0.2	0.2
Grades on Approach Streets	<3%	3.1 - 3.9%	4.0 - 4.9%	5.0 - 6.9%	7% or more	1	0.4	0.4
Curvature on Approach Legs	<3.0 deg.	3.0 - 6.0 deg.	6.1 - 8.0 deg.	8.1 - 10.0 deg.	>10.0 deg.	1	8.0	8
Parking in Vicinity	prohibited both sides	loading zones only	off-peak only	permitted one side only	permitted both sides	1	0.1	0.1
							GEOMETRIC TOTAL	16.2
Operational Factors								
Operating Speed on Approach Legs	25 mph or less	30 mph	35 mph	40 mph	45 mph or greater	5	0.8	4
Type of Control	all phases signalized (including turn lane)	left turn lane signal control	through traffic signal control only	4-way stop control	stop control to minor legs or no control	1	0.3	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	1.0	3
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)	4	0.8	3.2
Ped. Volume (peds/hr crossing)	very few or none	0-50	50-100	100-200	>200	3	1.0	3
							OPERATIONAL TOTAL	13.5
Environmental Factors								
% Adjacent Development	0	0 - 30%	30 - 60%	60 - 90%	100%	5	0.2	1
Predominant Development near intersection	undeveloped	residential	50% residential - 50% industrial or commercial	industrial or commercial	strip industrial or commercial (no circuitry)	4	0.2	0.8
Lighting in Immediate Vicinity	none	0 - 40%	40 - 60%	60 - 80%	essentially continuous	4	1.5	6
Crime Rate	extremely low	lower than City average	City average	Higher than City average	Extremely high	3	0.5	1.5
							ENVIRONMENTAL TOTAL	9.3
Accidents								
Ratio of night to day accident rates	<1.0	1.0 - 1.2	1.2 - 1.5	1.5 - 2.0	2.0*	1	8.0	8
*Continuous lighting warranted							**ACCIDENT TOTAL**	8
							SUM OF TOTALS =	47 **POINTS**
							WARRANTING CONDITION =	75 POINTS
							WARRANT MET?	**NO**

NCHRP 152 Lighting Warrants
Classification for Intersection Lighting at SR40 and Booth Rd
From Table 14 - Page 28

Classification Factor	Rating 1	2	3	4	5	Given Rating	Diff. (A-B)	Score [Rating X(A-B)]
Geometric Factors								
Number of Legs	-	3	4	5	6 or more	3	0.5	1.5
Approach lane width	>12'	12'	11'	10'	<10'	2	0.5	1
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	3	1.0	3
Approach Sight Distance	>700'	500 - 700'	300 - 500'	200 - 300'	<200'	1	0.2	0.2
Grades on Approach Streets	<3%	3.1 - 3.9%	4.0 - 4.9%	5.0 - 6.9%	7% or more	1	0.4	0.4
Curvature on Approach Legs	<3.0 deg.	3.0 - 6.0 deg.	6.1 - 8.0 deg.	8.1 - 10.0 deg.	>10.0 deg.	1	8.0	8
Parking in Vicinity	prohibited both sides	loading zones only	off-peak only	permitted one side only	permitted both sides	1	0.1	0.1
							GEOMETRIC TOTAL	14.2
Operational Factors								
Operating Speed on Approach Legs	25 mph or less	30 mph	35 mph	40 mph	45 mph or greater	5	0.8	4
Type of Control	all phases signalized (including turn lane)	left turn lane signal control	through traffic signal control only	4-way stop control	stop control to minor legs or no control	1	0.3	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	1.0	3
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)	3	0.8	2.4
Ped. Volume (peds/hr crossing)	very few or none	0-50	50-100	100-200	>200	3	1.0	3
							OPERATIONAL TOTAL	12.7
Environmental Factors								
% Adjacent Development	0	0 - 30%	30 - 60%	60 - 90%	100%	4	0.2	0.8
Predominant Development near intersection	undeveloped	residential	50% residential - 50% industrial or commercial	industrial or commercial	strip industrial or commercial (no circuitry)	4	0.2	0.8
Lighting in Immediate Vicinity	none	0 - 40%	40 - 60%	60 - 80%	essentially continuous	3	1.5	4.5
Crime Rate	extremely low	lower than City average	City average	Higher than City average	Extremely high	3	0.5	1.5
							ENVIRONMENTAL TOTAL	7.6
Accidents								
Ratio of night to day accident rates	<1.0	1.0 - 1.2	1.2 - 1.5	1.5 - 2.0	2.0*	1	8.0	8
*Continuous lighting warranted							**ACCIDENT TOTAL**	8
							SUM OF TOTALS =	42.5 **POINTS**
							WARRANTING CONDITION =	75 POINTS
							WARRANT MET?	**NO**

NCHRP 152 Lighting Warrants
Classification for Intersection Lighting at SR40 and I-95 SB Ramps
From Table 14 - Page 28

Classification Factor	Rating 1	2	3	4	5	Given Rating	Diff. (A-B)	Score [Rating X(A-B)]
Geometric Factors								
Number of Legs	-	3	4	5	6 or more	3	0.5	1.5
Approach lane width	>12'	12'	11'	10'	<10'	1	0.5	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	5	1.0	5
Approach Sight Distance	>700'	500 - 700'	300 - 500'	200 - 300'	<200'	1	0.2	0.2
Grades on Approach Streets	<3%	3.1 - 3.9%	4.0 - 4.9%	5.0 - 6.9%	7% or more	1	0.4	0.4
Curvature on Approach Legs	<3.0 deg.	3.0 - 6.0 deg.	6.1 - 8.0 deg.	8.1 - 10.0 deg.	>10.0 deg.	1	8.0	8
Parking in Vicinity	prohibited both sides	loading zones only	off-peak only	permitted one side only	permitted both sides	1	0.1	0.1
							GEOMETRIC TOTAL	15.7
Operational Factors								
Operating Speed on Approach Legs	25 mph or less	30 mph	35 mph	40 mph	45 mph or greater	5	0.8	4
Type of Control	all phases signalized (including turn lane)	left turn lane signal control	through traffic signal control only	4-way stop control	stop control to minor legs or no control	1	0.3	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	1.0	3
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)	3	0.8	2.4
Ped. Volume (peds/hr crossing)	very few or none	0-50	50-100	100-200	>200	3	1.0	3
							OPERATIONAL TOTAL	12.7
Environmental Factors								
% Adjacent Development	0	0 - 30%	30 - 60%	60 - 90%	100%	4	0.2	0.8
Predominant Development near intersection	undeveloped	residential	50% residential - 50% industrial or commercial	industrial or commercial	strip industrial or commercial (no circuitry)	4	0.2	0.8
Lighting in Immediate Vicinity	none	0 - 40%	40 - 60%	60 - 80%	essentially continuous	3	1.5	4.5
Crime Rate	extremely low	lower than City average	City average	Higher than City average	Extremely high	3	0.5	1.5
							ENVIRONMENTAL TOTAL	7.6
Accidents								
Ratio of night to day accident rates	<1.0	1.0 - 1.2	1.2 - 1.5	1.5 - 2.0	2.0*	5	8.0	40
*Continuous lighting warranted							**ACCIDENT TOTAL**	40
							SUM OF TOTALS =	76 **POINTS**
							WARRANTING CONDITION =	75 POINTS
							WARRANT MET?	**YES**

NCHRP 152 Lighting Warrants
Classification for Intersection Lighting at SR40 and I-95 SB Ramps
From Table 14 - Page 28

Classification Factor	Rating 1	2	3	4	5	Given Rating	Diff. (A-B)	Score [Rating X(A-B)]
Geometric Factors								
Number of Legs	-	3	4	5	6 or more	3	0.5	1.5
Approach lane width	>12'	12'	11'	10'	<10'	3	0.5	1.5
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	5	1.0	5
Approach Sight Distance	>700'	500 - 700'	300 - 500'	200 - 300'	<200'	1	0.2	0.2
Grades on Approach Streets	<3%	3.1 - 3.9%	4.0 - 4.9%	5.0 - 6.9%	7% or more	1	0.4	0.4
Curvature on Approach Legs	<3.0 deg.	3.0 - 6.0 deg.	6.1 - 8.0 deg.	8.1 - 10.0 deg.	>10.0 deg.	1	8.0	8
Parking in Vicinity	prohibited both sides	loading zones only	off-peak only	permitted one side only	permitted both sides	1	0.1	0.1
							GEOMETRIC TOTAL	16.7
Operational Factors								
Operating Speed on Approach Legs	25 mph or less	30 mph	35 mph	40 mph	45 mph or greater	5	0.8	4
Type of Control	all phases signalized (including turn lane)	left turn lane signal control	through traffic signal control only	4-way stop control	stop control to minor legs or no control	1	0.3	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	1.0	3
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)	3	0.8	2.4
Ped. Volume (peds/hr crossing)	very few or none	0-50	50-100	100-200	>200	3	1.0	3
							OPERATIONAL TOTAL	12.7
Environmental Factors								
% Adjacent Development	0	0 - 30%	30 - 60%	60 - 90%	100%	4	0.2	0.8
Predominant Development near intersection	undeveloped	residential	50% residential - 50% industrial or commercial	industrial or commercial	strip industrial or commercial (no circuitry)	4	0.2	0.8
Lighting in Immediate Vicinity	none	0 - 40%	40 - 60%	60 - 80%	essentially continuous	3	1.5	4.5
Crime Rate	extremely low	lower than City average	City average	Higher than City average	Extremely high	3	0.5	1.5
							ENVIRONMENTAL TOTAL	7.6
Accidents								
Ratio of night to day accident rates	<1.0	1.0 - 1.2	1.2 - 1.5	1.5 - 2.0	2.0*	5	8.0	40
*Continuous lighting warranted							**ACCIDENT TOTAL**	40
							SUM OF TOTALS =	77 **POINTS**
							WARRANTING CONDITION =	75 POINTS
							WARRANT MET?	**YES**

NCHRP 152 Lighting Warrants
Classification for Intersection Lighting at SR40 and Williamson Blvd
From Table 14 - Page 28

Classification Factor	Rating 1	2	3	4	5	Given Rating	Diff. (A-B)	Score [Rating X(A-B)]
Geometric Factors								
Number of Legs	-	3	4	5	6 or more	3	0.5	1.5
Approach lane width	>12'	12'	11'	10'	<10'	3	0.5	1.5
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	5	1.0	5
Approach Sight Distance	>700'	500 - 700'	300 - 500'	200 - 300'	<200'	1	0.2	0.2
Grades on Approach Streets	<3%	3.1 - 3.9%	4.0 - 4.9%	5.0 - 6.9%	7% or more	1	0.4	0.4
Curvature on Approach Legs	<3.0 deg.	3.0 - 6.0 deg.	6.1 - 8.0 deg.	8.1 - 10.0 deg.	>10.0 deg.	1	8.0	8
Parking in Vicinity	prohibited both sides	loading zones only	off-peak only	permitted one side only	permitted both sides	1	0.1	0.1
							GEOMETRIC TOTAL	16.7
Operational Factors								
Operating Speed on Approach Legs	25 mph or less	30 mph	35 mph	40 mph	45 mph or greater	5	0.8	4
Type of Control	all phases signalized (including turn lane)	left turn lane signal control	through traffic signal control only	4-way stop control	stop control to minor legs or no control	1	0.3	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	1.0	3
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)	4	0.8	3.2
Ped. Volume (peds/hr crossing)	very few or none	0-50	50-100	100-200	>200	3	1.0	3
							OPERATIONAL TOTAL	13.5
Environmental Factors								
% Adjacent Development	0	0 - 30%	30 - 60%	60 - 90%	100%	4	0.2	0.8
Predominant Development near intersection	undeveloped	residential	50% residential - 50% industrial or commercial	industrial or commercial	strip industrial or commercial (no circuitry)	4	0.2	0.8
Lighting in Immediate Vicinity	none	0 - 40%	40 - 60%	60 - 80%	essentially continuous	3	1.5	4.5
Crime Rate	extremely low	lower than City average	City average	Higher than City average	Extremely high	3	0.5	1.5
							ENVIRONMENTAL TOTAL	7.6
Accidents								
Ratio of night to day accident rates	<1.0	1.0 - 1.2	1.2 - 1.5	1.5 - 2.0	2.0*	4	8.0	32
*Continuous lighting warranted							**ACCIDENT TOTAL**	32
							SUM OF TOTALS =	69.8 **POINTS**
							WARRANTING CONDITION =	75 POINTS
							WARRANT MET?	**NO**

Attachment F
Benefit-Cost Analysis
Worksheets

Benefit Cost Analysis
SR 40 PD&E Study
Breakaway Trail to Williamson Blvd
Financial Project No. 428947-1-22-01

B-C Proposed Lighting Installation

Segment	Type	Length (mi.)	Existing ADT (2011)	MEV/MVM	%ADTn	# Total Crashes	# Nighttime crashes	Nighttime Crashes/Yr	Nighttime Crash Rate Unlighted (NRU)	Daytime Crash Rate	Night/Day Crash Rate Ratio	CRF	Crash Severity (Nighttime)			ACC	AIC	TMC	AEC	Benefit-Cost Ratio
													Fatal	Injury	PDO					
Tymber Creek Rd to Booth Rd	Segment	0.53	23400	4.53	23%	9	3	0.6	0.576	0.344	1.674	0.2	0	2	1	$107,538	$20,083.34	$3,610.00	$2,441.12	**0.93**
Booth Rd to I-95 SB Ramp	Segment	0.26	23800	2.26	23%	16	7	1.4	2.695	1.035	2.604	0.2	1	4	2	$1,003,604	$9,852.20	$1,900.00	$1,284.80	**82.90**
I-95 SB Ramp to Williamson Blvd	Segment	0.322	29700	3.49	23%	97	40	8	9.965	4.241	2.349	0.2	0	25	15	$101,223	$12,201.57	$2,280.00	$1,541.76	**31.39**
Tymber Creek Rd to I-95 SB Ramp	Segment	0.79	23400	6.75	23%	31	11	2.2	1.418	0.770	1.841	0.2	1	7	3	$682,354	$29,935.54	$5,320.00	$3,597.44	**9.78**

ADT = Average Daily Traffic (Existing or Projected)
%ADTn = Percent of ADT at night
NRU = Night crash rate unlighted
CRF = Crash Reduction Factor (HSM Table 13-56)
ACC = Average Crash Cost (U.S. dollars per crash)
AIC = Annualized installation cost
TMC = Total annual maintenance cost
AEC = Annual energy cost

MEV = Million Entering Vehicles (Intersections)
MVM - Million Vehicle-Miles (segements)
ADT = Average Daily Traffic (Existing or Projected)
%ADTn = Percent of ADT at night

Crash Costs (HSM/KABCO)
Fatal Crash $6,380,000
Injury Crash $158,057
PDO Crash $6,500

Crash Data 2007-2011
AADT for intersections based on 2011 turning movement counts with 0.97 peak season factor and 0.09 peak/daily "K" factor applied.
AADT for segments based on DTTM Figures 5-2 and 5-3

Assumptions:

Interest Rate:	4%	State Safety Office Bulletin 10-01
Life Cycle (years)	15	
Pole Spacing (ft) (one side of road):	150	Assumed from LRE Estimate
Annual Maintenance per luminaire:	$190.00	2% of initial pole cost ($9,375/pole)
Energy Cost ($/kWH):	$0.08	Estimate
Luminaire Wattage:	400	Assumed

Capital Recover (CRF) = 0.0899
No. Poles =

Tymber Creek to Booth Road	19
Booth Road to I-95	10
I-95 to Williamson	12
Tymber Creek to I-95	28

Initial Lighting Costs (Conventional urban lighting cost from LRE) = $421,310.00 per mile