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Geographic Information System Mapping of Roadway Lighting and Traffic Accidents

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***Abstract*—** The use of a Geographic Information System (GIS) in roadway lighting to show the state of street-lighting and nighttime accident is demonstrated. Geographical maps were generated showing colored streets based on how much of the street's length is illuminated. The night to daytime accidents ratio at intersections were found along with the state of lighting at those intersections. The result is a method to show the state of street-lighting at roads and intersections and a quick guide for decision makers to implement strategies for better street-lighting to reduce night time traffic accidents in a particular district.

***Keywords*—** GIS. Roadway lighting, Traffic Accidents.

I. Introduction

A GIS is a system for the management, analysis and, display of geographic information. The streets, parcels, addresses and, streetlights are stored in a geographic database [2]. The attributes of over 52,000 streetlight fixtures were saved in a geo-database. The attributes include the GPS coordinate of each pole, the wattage of the lamp and its type, the fixture style and pole style. The streets are represented by center lines whereas; major streets are represented by two lines, one for the centerline of each side. Once all this information is stored, an analysis was made to find the lighting conditions on the road and intersections. Fig. 1 shows a visual display of a neighborhood with symbols and labels indicating the type of streetlights used. The digital map of the subject area was exported from GIS into a DXF file which is then imported into lighting analysis software [5] where the lighting design or the analysis of the existing system are made as shown in Fig. 2.

The objective of this study is to overlay the lighting conditions at intersections with the night-daytime ratio of traffic accidents at those intersections and to highlight the percentage of the street that is lit relative to the total length of the street segment.

Whereas, Pain et al [6] has used GIS for street lighting and crime and fear maps, this paper focus on the night to day time ratio of traffic accidents. Abdalla [1] developed a method of locating street light poles from ortho-images. This paper uses the geo-coordinate of the poles in the database along with the attributes of the streetlight poles to analyze the illumination conditions.

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Fig. 1 Visual GIS display of a neighborhood with symbols and labels indicating the type of streetlights used.

II. METHODOLOGY

A. Roadway Lighting Analysis

To find what percentage of a particular street is lit, a circle is assigned to each streetlight. The circle represents the effective area of the light around the pole. The diameter of the circle was found using a Photometric optimizer [3] and the manufacturer photometric file as follows.

Fig. 2 An example of iso-illuminance contours of an intersection using an imported map from GIS.

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First, the typical road width and road classification for this particular lamp was identified. Consequently, the spacing was optimized using the Illuminating Engineering Society of North America (IES) RP-8 [4] Illuminance criteria. The diameter of the circle is equal to the optimum spacing between the poles that provides the IES recommended average illuminance and uniformity. This process is used to identify the diameter of the effective circle for each streetlight fixture used in the county. Table 1 lists the type of fixtures and the corresponding diameter of the effective circle used.

The intersections between each circle and the centerline of the street are found and summed to give the linear length of the street that is lit. This process is illustrated in Fig. 3 and Fig. 4. The percentage of the street that is lit is obtained by dividing the length of the street that is lit by the total length of the street. Once this analysis is done, a summary of the state of street-lighting in a district can be obtained as illustrated in Table . Fig. 5 and Fig. 6 show samples of the output generated by this analysis.

Fig. 3 Intersection between the effectively lit circle with the centerline of streets. Blue circles represent Mercury Vapor lamps. Two lines represent centerline of two way streets.

B. *Intersection Conditions*

To analyze intersections, the numbers of streetlight poles that are within 125 ft radius of the center of the intersection were found excluding any Mercury Vapor Lamp since this type of lamps are considered obsolete. Then the ratio of the night time accidents relative to daytime accidents within 250 ft radius from the intersection was found. This process is shown in Fig. 4.

To overlay the traffic accidents condition in intersections on the number of streetlights covering the intersection, reportable crashes that occurred over a three-year period, from 1/1/2002 through 12/31/2004, were extracted using the county police department crash data.

From that dataset, crashes that occurred more than 250 feet from the listed intersection were dropped. This resulted in 43,552 crash records at 8,009 intersections. Accident time was "rounded" using a floor-type method, for example, all crashes that occurred from 0800 a.m. through 0859 a.m. were assigned an "Accident Hour" of 8. Using the 24-hour clock, crashes from 0800 p.m. through 0859 p.m. were assigned an Accident Hour of 20.

TABLE 1 THE TYPE OF FIXTURES AND THE CORRESPONDING EFFECTIVE CIRCLE DIAMETER

Fixture	**Lamp**	**Wattage**	**Effective Circle Diameter(ft)** using Circle intersection with street centerline
Enclosed Flat Lens	HPS	70	115
		100	130
		150	130
		250	200
		400	195
Enclosed Drop Lens	HPS	70	140
		100	160
		150	115
		250	115
		400	180
Enclosed Flat Lens	Mercury Vapor	100	150
		175	150
		250	150
		400	150
Interstate	HPS	250	170
		400	180
Acorn and Carlyle	HPS	70	50
		100	75
		150	50
Colonial	HPS	70	130
		100	130
		150	130
DECA	Metal Halide	175	90
		250	160
		400	185

TABLE II SUMMARY OF THE STATE OF LIGHTING IN ONE DISTRICT OF THE COUNTY OBTAINED FROM THE ANALYSIS

Road Classification	Total Road Distance (Miles)	Total Lit Miles	Total Unlit Miles
FREEWAYS/EXPRESSWAYS	7.21	0.00	7.21
MAJOR ARTERIALS (TYPE B)	23.66	8.78	10.6
MINOR ARTERIALS (TYPE A)	21.12	4.93	14.4
OTHER	311.65	37.42	176
PRINCIPAL ARTERIALS	12.48	1.84	9.69
UNKNOWN	0.29	0.00	0.19

The crashes were labeled as having occurred during the night or day based on the accident hour, the month and, the sunset and sunrise time for the region as listed in

At this point, any intersection from the analysis that had fewer than 10 total reportable crashes over the three-year period was dropped, which resulted in 973 intersections remaining in our analysis.

Using Table the total number of "day hours" and "night hours" was calculated for one year, using 365.3 days in a year. For each intersection, a total number of daytime accidents (over the three years) was calculated. Because of daylight savings time, there is more daytime hours than night time hours. To adjust for this, day crash per day hour value was used. The intersection's rate of Daytime Crashes per Daytime Hour was calculated using the following equation:

$$\text{Day Crash per Day Hour} = \frac{(\text{Day Crashes}) * (1 \text{ year})}{(3 \text{ year} * 4507.63 \text{ Day Hours})}$$

The same calculation was done for Night Crashes per Night Hour, using 4259.57 Night Hours in one year. A ratio was then calculated, Night Crashes per Night Hour over Day Crashes per Day Hour. This ratio, Night over Day, was used in our final analysis.

Of the 973 intersections, 132 had a Night over Day ratio greater than 1.00 meaning that there are more accidents during night time than daytime. These intersections that were the focus of this study, in hopes of determining if the surrounding lighting conditions were related to a higher than expected nighttime crash rate.

Of the 132 intersections, 13 had a Night over Day ratio greater than 2.00. All of the thirteen intersections had fewer than 4 lights and consequently will not satisfy the IES standards. Twenty two intersections had night-day time accidents ratio between 1.5-2 X. Of those 22 intersections, 21 intersections had less than 4 lights. In fact of the 132 intersection with night to day accidents ratio grater than one, only 7 intersections had more 4 lights or more. That is 85% of the intersections with night to day accidents ratio greater than 1, have less than 4 light poles. An example of the output of this analysis is illustrated in Fig. 7.

TABLE III SUNSET AND SUNRISE TIME FOR FAIRFAX CITY ON THE 21ST OF EACH MONTH [7]

Date (21st of the month)	Sunrise	Sunset	Rounded off Sunrise Time	Rounded off Sunset time
January	7:23	5:18	7	5
Feb	6:52	5:54	7	6
Mar	6:11	6:22	6	6
April	6:24	7:52	6	8
May	5:52	8:20	6	8
Jun	5:44	8:38	6	9
Jul	6:01	8:30	6	9
Aug	6:28	7:55	6	8
Sep	6:56	7:08	7	7
Oct	7:25	6:22	7	6
Nov	6:58	4:51	7	5
Dec	7:24	4:51	7	5

III. CONCLUSION

The use of GIS in street-lighting application was demonstrated. Streets were colored according to the illuminated length of the street. Lighting at intersections along with night to daytime accidents ratio was analyzed and maps were generated to show intersections with relatively high night to day time accidents ratio. It was found that 85% of the intersections that had a high number of nighttime accidents relative to daytime, did not satisfy the IES recommended illumination levels.

It should be noted that this study is not an attempt to attribute accidents to lighting conditions as there are many other reasons why an accident occurs. The advantage of this study is to guide decision makers to trouble spots and to assist them on allocating resources to improve street lighting conditions.

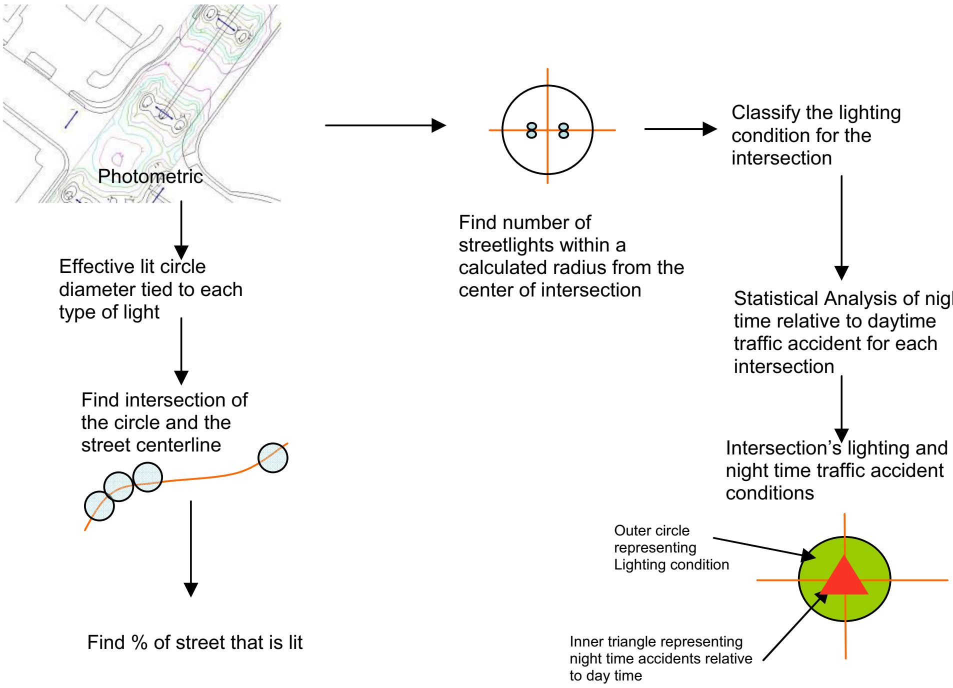
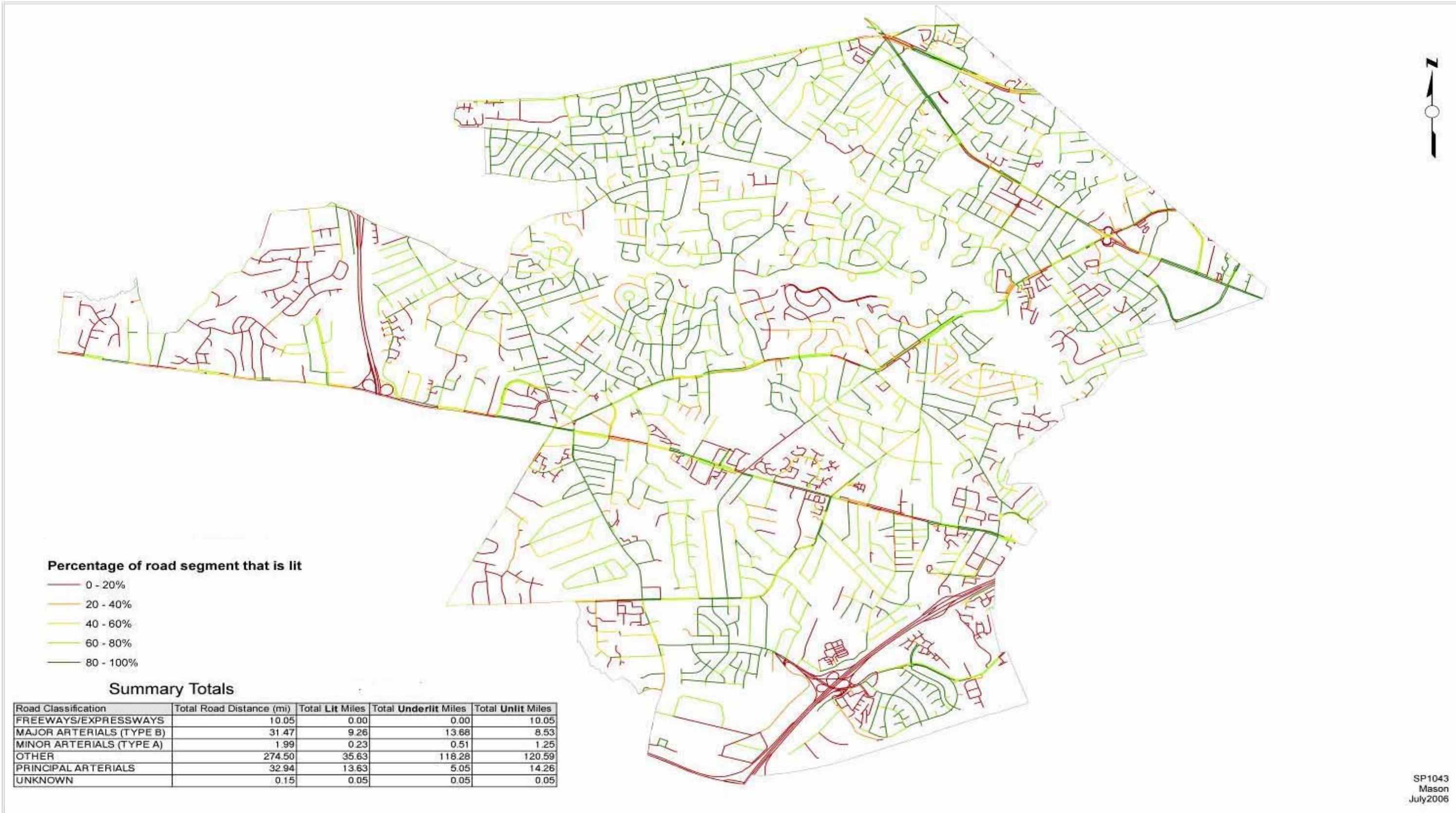


Fig. 4 Analysis of streetlight conditions



Road Classification	Total Road Distance (mi)	Total Lit Miles	Total Underlit Miles	Total Unlit Miles
FREEWAYS/EXPRESSWAYS	10.05	0.00	0.00	10.05
MAJOR ARTERIALS (TYPE B)	31.47	9.26	13.68	8.53
MINOR ARTERIALS (TYPE A)	1.99	0.23	0.51	1.25
OTHER	274.50	35.63	118.28	120.59
PRINCIPAL ARTERIALS	32.94	13.63	5.05	14.26
UNKNOWN	0.15	0.05	0.05	0.05

Fig. 5 Mapping of the percentage of illuminated segments of streets in a district of the county

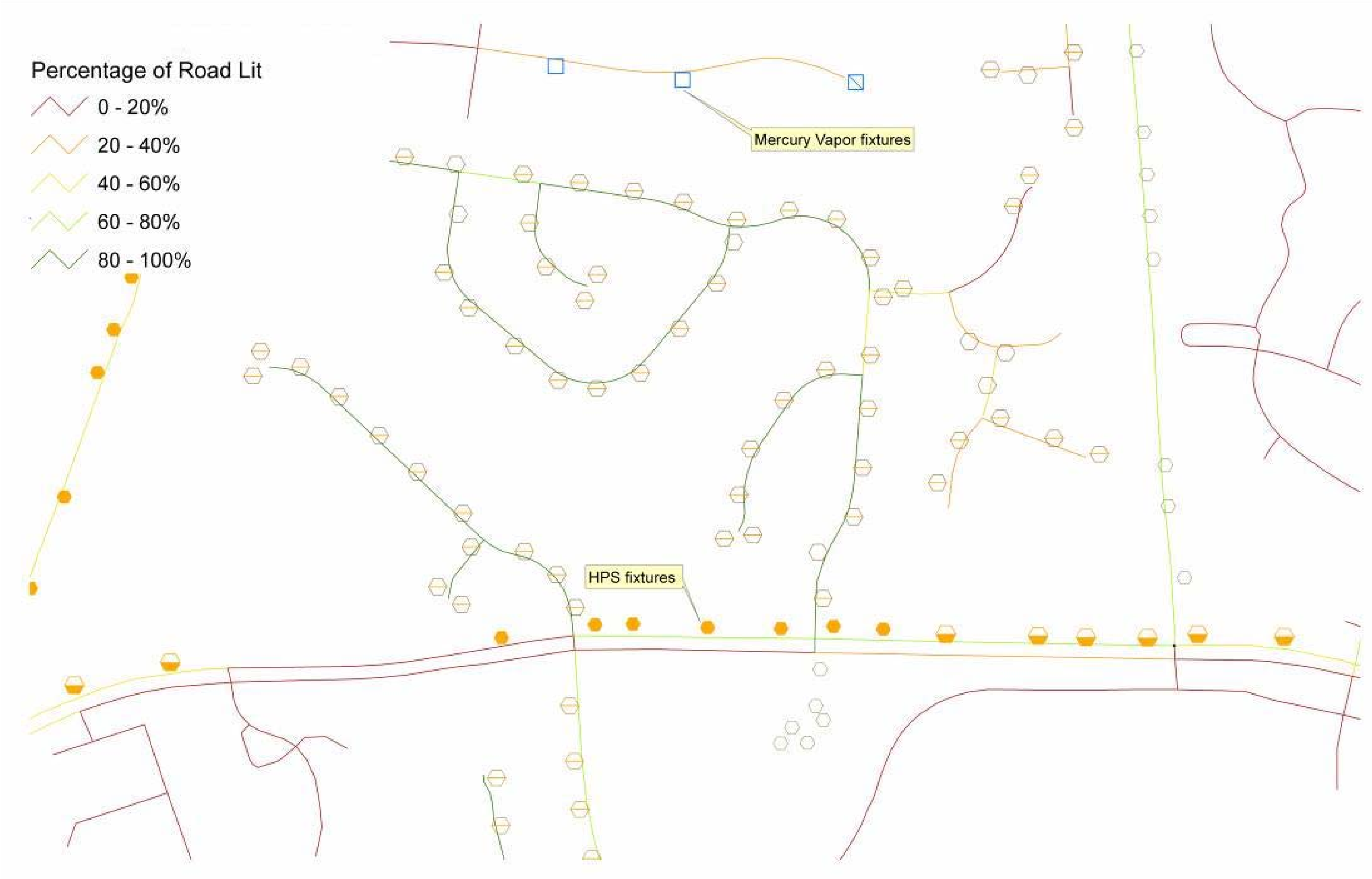


Fig. 6 A close-up view showing different types of fixtures such as colonial high pressure sodium, mercury vapor cobra head, and cobra head with high pressure sodium. The lines are the center lines of the road with two lines representing the centerline of each way in a two way streets. The center line of the street is colored according to how much of the street is lit

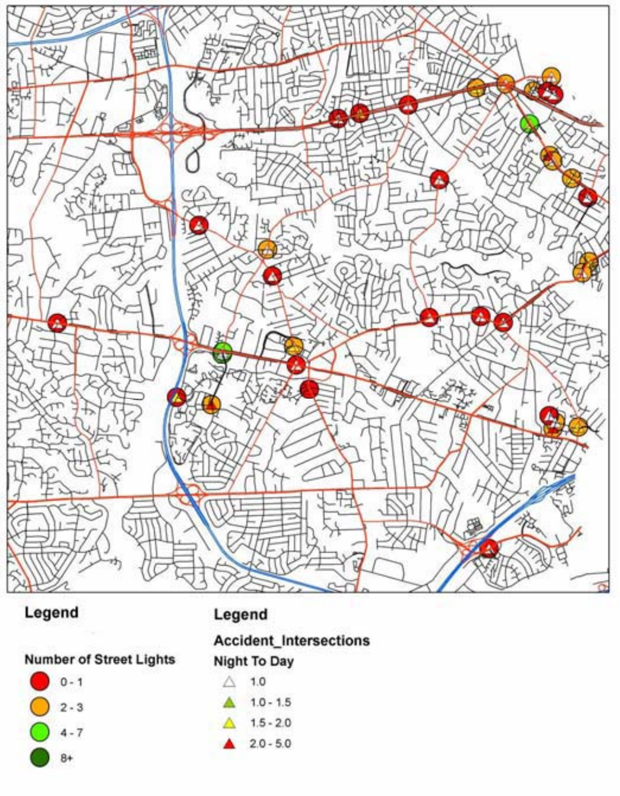


Fig. 7 Traffic accidents within 250 ft of an intersection overlaid with the number of light poles within 125 ft radius of an intersection.

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Riad Saraiji has over 15 years of experience in Illumination system design and engineering in the United States. He has been involved in lighting design of Museums, Retail Malls, Parking lots and roadways. He has conducted projects for leading international organizations such as Carrier Corporation, NASA, US National Science Foundation, US National Institute of Standards and Technology, Osram Sylvania, Savola (KSA) and EMAAR (KSA). Mr. Saraiji has a PhD in Architectural Engineering (Illumination Engineering emphasis) from the Pennsylvania State University (USA). He was a member of the faculty of the School of Engineering Technology of Pennsylvania State University from 1993-1997, president of Illumitech, LLC, Vienna, Virginia from 1997-2005, visiting lecturer at the department of Mechanical Engineering of the University of Maryland 2000-2004, and is currently Associate Professor of Architectural Engineering, United Arab Emirates University.