# An Examination of an Illuminated Bike Path in a Southern U.S. Town

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**ABSTRACT—** ***An illuminated pedestrian and bike path in a southern U.S. town was examined for this study. The U.S. state where this study was conducted is ranked in the top 50% for fatal pedestrian crashes in the United States of America. The path, with sections both near to and distant from the roadway, bordered a University campus in the southern U.S. and served to link existing University buildings, a University/community arena and parking. Researchers empirically examined existing lighting conditions along the proposed path in 2005, considering existing spill lighting from nearby buildings and roadways. Following industry procedures, they took sample light meter readings utilizing a hand-held lux meter. After a five year delay in Federal funding, construction on the illuminated pedestrian and bike path project commenced. After the path's completion in 2012, the researchers re-measured light levels at the site. They compared their pre- and post-installation measurements to the industry recommendations, the IESNA lighting recommendations for pedestrian and bike paths in effect during these two time periods. After the new lighting was installed, light levels measured in 2012-13 and the light levels were much more even. The path is currently in use by University and community stakeholders. Safety and security concerns had spurred interest in the design and construction of an illuminated pedestrian and bike path. This paper begins to fill a gap in the literature regarding empirical case studies of pedestrian and bike path lighting installations.***

**Keywords—** crash, safety, security, outdoor, pedestrian, bicycle, lighting, community, field study

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## 1. INTRODUCTION

According to the National Survey of Pedestrian and Bicyclist Attitudes and Behaviors which included a total of 9,616 telephone interviews with U.S. residents age 16 or older, approximately 43% of people rode a bicycle at least once during the summer of 2002. It was also reported that 46% of people had access to bicycles for their regular use. Bicycling can be used as a way for U.S. people to manifest their emphasis on fitness and health, which has emerged as one of Americans' core values [22]. It can also help people get plenty of physical activity and thus maintain a healthy weight [6]. In addition, bicycling can replace motorized vehicles because cyclists can cover great distances with fast speed [6]. Although several states and cities in the U.S. have made aggressive efforts to promote bicycling through policies and programs [17], the results are still small in comparison to the number of bicycling trips made in European countries such as the Netherlands and Germany [10]. Moreover, most of people in the U.S. ride a bicycle for recreation, not daily travel [6].

The features of a bike path include that is a stand-alone facility, whose width is less than a road and is mostly frequented by bicyclists but sometimes utilized also by other non-motorized traffic [1]. Although findings from previous pedestrian and bike path studies are somewhat mixed, in general, bicyclists would rather cycle on dedicated paths to cycling in mixed traffic [1,10]. Perceptions of path safety may influence the cyclists' preference. Bicycle crash reports in previous studies indicated less crashes on dedicated bike paths than on roadways [14,21]. Bicycle safety awareness has discouraged some cyclists [7,16]. According to the National Survey of Pedestrian and Bicyclist Attitudes and Behaviors [15], more than 13% of respondents perceived bicycling as an unsafe activity, with concerns expressed regarding automobiles, non-level surfaces, dogs and other animals, and personal security. Therefore, to encourage participation in

cycling in the U.S., including for everyday travel, it is imperative to provide specialized facilities such as bike paths. Illuminating bike paths to recommended levels will increase night-time safety thereby encouraging the frequency of cycling, even at night. Proper lighting may help to ensure the safety of pedestrian and bicyclists, as the night-time environment may be more threatening or present more risks than the daytime environment.

## 2. PURPOSE

Pedestrian and bike path illumination were the focus of this study. The U.S. state where this study was conducted is currently rated in the top 50% for fatal pedestrian crashes in the U.S. [23]. In the design and construction of an illuminated pedestrian and bike path, safety and security concerns in the area had spurred interest. The purpose of this study was to perform a case study on a pedestrian and bike path. Researchers examined crash reports for the area and studied lighting conditions at the recently completed pedestrian and bike path by conducting night-time field measurements of existing illumination and comparing them to lighting industry recommendations, for pedestrian and bike paths. Empirical data were gathered pre- and post- new lighting installation. The sky quality (levels of light pollution) near the path was also examined. The objectives of the study included 1) investigating crash reports in the bike path area, 2) examining and recording lighting empirical measurements along a pedestrian and bike path pre- and post-illuminated path construction and 3) comparing results to the Illuminating Engineering Society of North America (IESNA) lighting recommendations for pedestrian and bike paths.

## 3. LITERATURE REVIEW

### *3.1 Definitions*

The interdisciplinary discipline of lighting design and visual perception utilizes unique terminology. Terms applicable to the bike and pedestrian path study are defined below:

a) *Color Rendering Index (CRI):* "…characterized by assigning a single number index to a light source that is computed using CIE colorimetry…The CIE Test-Color Method rates lamps using indices of color rendering that represents the degree of resultant color shift of a test object under a test lamp in comparison with its color under a reference illuminant of the same Correlated Color Temperature (CCT)" [5].
b) *Light Pollution:* "Involves light that is directed skyward, hindering or eliminating the view of the starlit sky on clear nights" [5].
c) *Light Trespass:* "…light that leaves a site and strikes a neighboring property, which may be considered a nuisance" [5].
d) *Mesopic:* "This operating state of the visual system is intermediate between the photopic and scotopic states. In the mesopic state both cones and rod photoreceptors are active. Luminances below approximately 10 cd/m² and above approximately 0.001 cd/m² produce this state of adaption" [5].
e) *Photopic:* "This operating state of the visual system occurs at luminances higher than approximately 10 cd/m². For these luminances, the visual response is dominated by the cone photorecpetors. This means that color is perceived and fine detail can be resolved in the fovea" [5].

### *3.2 Pedestrian and Bike Path Illumination*

Bicyclists incur a higher number of injuries requiring hospitalization than do motor vehicle occupants; therefore, understanding ways of making bicycling safer is important to increasing rates of bicycling and improving population health. Reynolds, Harris, Teschke, Cripton, and Winters [20] suggested that infrastructure influences injury and crash risk. They showed that purpose-built bicycle-specific facilities may reduce crashes and injuries among cyclists. Spaces that are poorly illuminated and used after dark increase the likelihood of accidents and invite crime. Kim, Kim, Ulfarsson, and Porrello [12] conducted a study to determine the factors contributing to the injury severity of bicyclists in bicycle-motor vehicle accidents. Darkness in the absence of streetlights was one of factor which more than doubled the probability of a bicyclist suffering a fatal injury in an accident. The correct lamps (light bulbs), appropriate lighting fixtures, proper maintenance, and lighting design that follow the IESNA's Guideline for Security Lighting for People, Property, and Public Spaces resulted in feelings of safety [13]. Willis, Powe, and Garrod [24] investigated the benefits of improved streetlights, associated with the replacement of low-pressure sodium streetlights with high-pressure sodium streetlights. High-pressure sodium offers higher CRI than low-pressure sodium. In Willis, Powe, and Garrod's [24] study, improved street lighting provided higher luminosity, improved color rendition of outdoor objects and created less light pollution. Other benefits included reductions in crime and road accidents, streetscape enhancements and increased amenity attributable to less light pollution.

Appropriately illuminated bike paths offer increased safety and allow for longer use of paths after dusk. When installing lighting in a multipurpose, heavily used corridor, which pedestrians and bicyclists utilize every day, light

pollution needs to be considered. The problem of light pollution affects local residents who do not want light shining into their back yards during all hours of the night. Immediately adjacent residents might not be supportive of a bike path light installation. Hesselberg [9] described a case where bike path users and surrounding residents debated the issues of a lighting installation on the competing intents of increasing safety and decreasing light trespass. The city decided to implement a lighting fixture that, if installed, would channel light downwards rather than outwards by way of a louvered lamp shade. The International Dark Sky Association (IDA) recommends the use of cut-off fixtures, with no uplight to mitigate light pollution and light trespass [3]. Some believe there is a correlation between light levels and a decrease in crime but others disagree. The IDA stated "Our cities have never been brighter, yet the crime rate is higher than ever" [4].

## 4. METHODS

Twenty students and four faculty team members actively participated in this pedestrian and bike path project over time. The team considered local bicycle crash data and industry lighting recommendations. The researchers measured illuminances for pre- and post-installation conditions. The data were analyzed utilizing descriptive statistics. Various software programs, including AutoCAD, Excel, Word, and Photoshop, were utilized to propose new lighting.

The team acquired and examined pedestrian and bicycle traffic crash reports produced by others during 2008-2013 to search for relevant issues. Crash reports from the state level, county level and town level were analysed using descriptive statistics. In 2005, team members examined existing lighting conditions along the two mile length of a proposed new pedestrian and bike path. The path was intended to link the edges of an existing University campus with the University's growing research park. Parts of the proposed path were adjacent to existing roadways and parking lots and also crossed vehicular roadways (See Figures 1 and 2). Several large, existing buildings frequented by the local community were situated along the proposed path; residential areas were also located nearby but not adjacent.

Following industry procedures, the researchers sampled light levels along the proposed pathway utilizing a hand-held lux meter, Extech Instruments 403123 meter (See Figure 3). Since path lighting was not yet installed, researchers considered current spill lighting contributions along the proposed path from existing pole mounted lights, building mounted lights from nearby structures, and light fixtures illuminating existing minor sidewalks and adjacent roadways. The collected lighting data were utilized by a larger design team to develop a lighting design solution, which was accepted by the University, the community and the Federal funding agency.

Later in 2005, a catastrophic natural disaster, Hurricane Katrina, occurred in the southern U.S. state where the project was located. The extensive and costly recovery that followed pre-empted the available Federal funding for construction projects in the state. Construction on the proposed, illuminated pedestrian and bike path project was delayed. Five years later when monies were again available, the project was resurrected and the installation commenced. A total of 179 nostalgic style, acorn-shaped fixtures, lamped with 100 watt high-pressure sodium lamps and mounted on 9'-6" poles, were installed along the new pedestrian and bike path (See Figure 4). The pedestrian and bike path project garnered public interest, and several print articles appeared in local media which documented the project's process, progress and perceptions.

After the illuminated path's completion, the researchers re-measured the lighting at the pedestrian and bike path site utilizing a hand-held lux meter (Extech Instruments 403123 meter). The bike path pavement was visually matched to a Light Reflectance Value (LRV) chart found in a commercial paint selector deck. The researchers also used a digital sky quality meter (Unihedron SQM) to measure sky quality to determine light pollution levels in the vicinity of the path in mags/arcsecond$^2$.

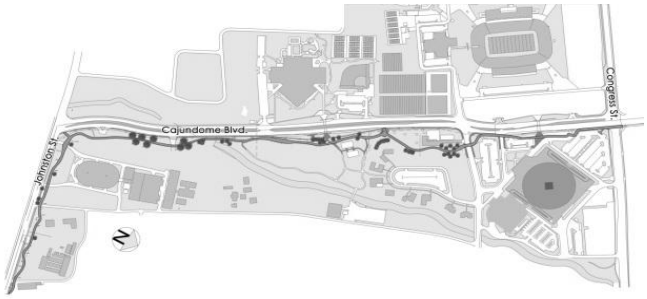


**Figure 1:** Map of the Proposed Two Mile Pedestrian and Bike Path Project. Courtesy of University of Lousiana at Lafayette, Community Design Workshop

**Figure 2:** Rendering of Proposed Pedestrian and Bike Path. Courtesy of University of Louisiana at Lafayette, Community Design Workshop

**Figure 3:** Researcher Utilizing Light Meter to Measure Light Levels

**Figure 4:** View of Completed Pedestrian and Bike Path with Acorn-Style Pole Fixtures and Pavement Surface LRV of 39%

## 5. RESULTS

### *5.1. Crash Trends*

The team acquired available bicycle crash data for 2008-2013. The state where the study was located is divided into 64 local government areas, generally known in the U.S. as "counties". Data was reported by state and county. In 2012, the U.S. Census Bureau estimated the state population as 4,601,893 and the county population as 227,055 [18]. The researchers determined that crashes in the state involving bicycles were generally increasing over time and that the county's bicycle crashes exceeded the state's averages for counties in some categories. Some bicycle crashes involved pedestrians and/or vehicles. Crashes continue to be an important issue (See Tables 1, 2 and 3).

**Table 1:** State bicycle crash frequency

| Year | Fatalities | # injured | *# of bicycles in crashes* |
|---|---|---|---|
| 2008 | 10 | 637 | 785 |
| 2009 | 12 | 597 | 774 |
| 2010 | 11 | 600 | 760 |
| 2011 | 16 | 654 | 851 |
| 2012 | 24 | 693 | 911 |
| 2013* | 22 | 672 | 891 |

Data Reports Highway Safety Research Group, Louisiana Crash Data Reports.
*Data reported through July, 2013 only.

**Table 2:** 2013 County bicycle crashes vs. state average bicycle crashes*

| | Fatal crashes | Fatalities (all) | Vehicles | *Bicycle fatalities* | *Injuries (all)* |
|---|---|---|---|---|---|
| **Country** | 16*** | 17*** | 29 | 0 | 25 |
| **State average*** | 10.7 | 11.0 | 34.4 | 0.3 | 27.3 |

Data Reports Highway Safety Research Group, Louisiana Crash Data Reports.
*Data reported through July 8, 2013 only.
**For counties with over 100,000 licensed drivers.
***County averages exceeding state averages.

**Table 3:** 2008 - 2011 Town bicycle crash frequency*

| | Fatal crashes | Total crashes | *Injuries (all)* |
|---|---|---|---|
| *Includes west end area of new bike path | 1 | 50 | 31 |

Lafayette Consolidated Government Traffic and Transportation Department.

### *5.2. Industry Recommendations Change*

The researchers found the IESNA's lighting recommendations for pedestrian and bike paths have changed over time and the compliance of the pedestrian and bike path under study varied (See Tables 4 and 5). Lighting level recommendations in 2000 were found to be more prescriptive whereas 2011 recommendations advocated a more custom approach with the consideration of many variables. Additionally, the recommended measurement height for vertical light levels and the overall vertical measurement procedures were modified during the bike path project's timeframe. Generally the light level recommendations have decreased over time. Also, the 2000 recommended singular measurement protocol at 1.83 meters (6'-0") height was changed to a recommendation of dual opposing planes measurements at 1.53 meters (5'-0") height in 2011. The latter was intended to more accurately account for the illumination of the faces of pedestrians and bicyclists.

Standard measurements for sky quality are relatively new. As recent as 2005, relatively inexpensive sky quality meters were in common use. Some were distributed to lighting educators who were interested in light pollution assessment. A relatively low measurement (roughly 19 mags/arseconds² or lower) is considered evidence of poor light quality or light pollution.

### *5.3. Calculating Target Illuminances*

Following the method indicated in the current, 2011 IESNA recommendations [5], the researchers referred to the associated tables to recreate the current target illuminance recommendations utilized for this pedestrian bike path. First the researchers established a "nighttime outdoor lighting zone". Based on their field observations of the bike path's conditions, the researchers selected "*LZ3," "moderately high ambient lighting"*, with "areas of human activity where the vision of human residents and users is adapted to moderately high light levels" where "lighting is generally desired for safety, security and/or convenience and it is often uniform…" Next, the researchers established the "activity level" as "*outdoor medium*" which includes "areas with relatively moderate volumes of pedestrians and vehicles or solely people during dark hours…" Based on field observations, the researcher then selected the: "*25 to 65 visual ages of observers (years) where at least half*" are this age. They additionally selected the category "*slow-to-moderate-paced situations*". After also considering that the stakeholders were especially interested in facial recognition, safety and security along the path, the selected parameters led researchers to establish the photopic illuminance criteria of: 6 lux (0.56 footcandles) "*horizontal"* and *2* lux (0.19 footcandles) *"vertical"*. Then the researchers "estimated surface reflectances", the reflectance values of the surface of the path (39%) and the surroundings (39% - 5%). Of special consideration was the installed high efficacy light source, high-pressure sodium, which had been chosen for the pedestrian and bike path installation in the current. High pressure sodium lighting has implications for mesopic adaption. The IESNA-recommended mesopic adaption multiplier of 1.3 was applied. Therefore, using current recommendations the adjusted horizontal illuminance target for this pedestrian and bike path project was determined by researchers to be 7.8 lux (.80 footcandles), and the adjusted vertical illuminance target was set at 2.6 lux (0.24 footcandles).

**Table 4:** Recommended illuminance for pedestrian and bikeways

| **Illuminating Engineering Society (IESNA) 2000** | | | **IESNA 2011** | |
|---|---|---|---|---|
| **Horizontal** | **Lux (LX)** | **Footcandles (FC)** | **Lux (LX)** | **Footcandles (FC)** |
| Average – Commercial | | | | |
| Average - Intermediate | 10.00* | 1.00* | NA | NA |
| Average – Residential | 5.00- 6.00* | 0.05 - 0.06* | 7.80* | 0.80* |
| Maximum: Minimum Uniformity | 2.00* | 0.02* | NA | NA |
| Ratio | 10:1 | 10:1 | 10:1 | 10:1 |
| Average: Minimum | 4:1 – 10:1 | 4:1 – 10:1 | 4:1 | 4:1 |
| Uniformity Ratio | | | | |
| **Vertical** | | | | |
| Average – Commercial | 22.00*** | 2.20*** | NA | NA |
| Average – Intermediate | 11.00*** | 1.10*** | 0.25-8.00** | 0.03-0.80** |
| Average – Residential | 5.00*** | 0.50*** | NA | NA |
| **Considerations**** | | | | |
| Activities and tasks | | + | | + |
| Surface reflectances | | + | | + |
| Photopic vision | | + | | + |
| Uniformities | | + | | + |
| Scotopic vision | | + | | + |
| Observers usual age | | O | | + |
| Activity level | | O | | + |

| | | |
|---|---|---|
| Nighttime ambient lighting zone | O | + |
| Mesopic vision | + | + |
| Mesopic adaption for high pressure sodium lighting | O | + |
| Road adjacency | + | + |
| Light trespass & light pollution | + | + |
| Color appearance | + | + |
| Modeling of faces & objects | + | + |

*At grade.
**At 1.52 meters (5'-0") above grade.
***At 1.83 meters (6'-0") above grade.
****The IESNA Lighting Handbooks (DiLaura *et al.*, 2011)[24] ask designers to consider many criteria before determining the appropriate target light levels for a particular application including: anticipated activities, nighttime outdoor lighting zone, outdoor activity level, light source, pavement reflectance value and observers' ages.

Note: The IESNA "orientation" category for "recommended illuminance targets" ranges from 0.5 – 60 lux (0.5 – 6 fc) for "visual performance is typically not work-related but related to dark sedentary social situations, senses of *safety and security*, and casual circulation based on landscape, hardscape, architecture, and people as visual tasks." (DiLaura *et al.*, 2011).
NA: Not Available.

**Table 5:** Measured illuminance for pedestrian and bike path

| **Pre-installation (2005)** | | | **Post-installation (2012-13)** | |
|---|---|---|---|---|
| **Horizontal** | **Lux (LX)** | **Footcandles (FC)** | **Lux (LX)** | **Footcandles (FC)** |
| Minimum | 1.08* | 0.01* | 3.34* | |
| Maximum | 77.61* | 7.21* | 33.91* | |
| Mean | 4.84* | 0.45* | 17.11* | |
| Maximum: Minimum uniformity ratio | 72:1 | 72:1 | 10:1 | |
| Average: Minimum uniformity ratio | 4.5:1 | 4.5:1 | 5:1 | |
| **Vertical** | | | | |
| Minimum | NA | NA | 5.27**<br>29.06*** | 0.49**<br>2.7*** |
| Maximum | NA | NA | 41.12**<br>40.90*** | 3.82**<br>3.8*** |
| Mean | NA | NA | 24.33**<br>32.61*** | 2.26**<br>3.03*** |
| Maximum: Minimum uniformity ratio | NA | NA | 7.8:1**<br>1.4:1*** | 7.88:1**<br>1.4:1*** |

*At grade.
**At 1.52 meters (5'-0") above grade.
NA: Not Available.

### *5.4. 2005 In-Situ Measurements*

In-situ, 660 individual light meter readings of existing illuminance were taken at night. The maximum horizontal light level was found to be 77.61 lux (7.21 fc). The minimum horizontal level was 1.08 lux (0.01 fc). The mean was 4.84 lux (0.45 fc). The maximum to minimum uniformity ratio in the horizontal plane was found to be 72:1. No vertical light levels were taken.

### *5.5. 2012-13 In-Situ Measurements*

After the lighting was installed along the path in 2012, a sample of 143 horizontal and vertical footcandle measurements were taken. At grade, the maximum *horizontal* light level was measured to be 33.91 lux (3.15fc). The minimum horizontal light level was found to be 3.34 lux (0.31fc). The mean was 1.76 lux (1.65 fc). The maximum to minimum uniformity ratio in the horizontal plane was 10:1. At 6-0" above grade, the maximum *vertical* light level was 40.90 lux (3.8 fc). The minimum vertical light level was 29.06 lux (2.7 fc). The mean was 32.61 lux (3.03 fc). The maximum to minimum uniformity ratio in the vertical plane was 1:1. At 5'-0" above grade, the maximum *vertical* light level was 41.12 lux (3.82 fc). The minimum vertical light level was

5.27 lux (0.49 fc). The mean was 24.33 lux (2.26 fc). The maximum to minimum uniformity ratio in the vertical plane was 8:1. Table 6 shows the comparison of light level recommendations to measurements (See Table 6).

**Table 6:** Comparison of light level recommendations to measurements

| **Recommendations (2000)** | | | **Measurements (2012-13)** | | **Recommendations (2011)** | |
|---|---|---|---|---|---|---|
| **Horizontal** | **Lux (LX)** | **Footcandles (FC)** | **Lux (LX)** | **Footcandles (FC)** | **Lux (LX)** | **Footcandles (FC)** |
| Average | 10.00* | 1.00* | 17.11* | 1.59* | 7.80* | 0.80* |
| Maximum: Minimum uniformity ratio | 10:1 | 10:1 | 10:1 | 10:1 | 10:1 | 10:1 |
| Average: Minimum uniformity ratio | 4:1 – 10:1 | 4:1 – 10:1 | 5:1 | 5:1 | 4:1 | 4:1 |
| **Vertical** | | | | | | |
| Average | 22.00*** | 2.20*** | 24.33**<br>32.61*** | 2.26**<br>3.03*** | 2.6** | 0.24** |
| Minimum uniformity ratio | NA | NA | 8:1**<br>1:1*** | 8:1**<br>1:1*** | NA | NA |

*At grade.
**At 1.52 meters (5'-0") above grade.
***At 1.83 meters (6'-0") above grade.
NA: Not Available.3

In later standards books, industry recommendations became more customized and many more variables were considered. Generally, the light level recommendations from 2011 [12] were found to be lower than those recommended in 2000 [19]. The recommended method for taking vertical measurements was changed such that heights above grade were reduced from 1.83 meters (6'-0") above grade to 1.53 meters (5'-0") above grade, one foot further away from the light source in 2011 as compared to 2000. However, the 2000 recommendations differentiated between residential, intermediate and commercial pedestrian and bike paths. Other changes in the decade spanning the release of the two industry lighting recommendations indicated that universities may have become more concerned about safety and security along pedestrian and bike paths and may equate higher light levels with more safety and security. Some may equate overage with waste while others may see increased light levels as insurance against accidents and crime.

### *5.6. Sky Quality Meter Levels*

SQM levels were taken at six points approximately equidistant along the pedestrian and bike path. The minimum SQM level was found to be 11.3 mags/arcsecond² and the maximum was 15.3 mags/arcsecond². The SQM mean measurement at the site was 14.74 mags/arcsecond². By visual examination, it was determined that the LRV of the path pavement was approximately 39%.

## 6. DISCUSSION AND CONCLUSION

The current study utilized relatively simple and repeatable methods with portable and relatively inexpensive instruments. Pre- and post- installation light levels were considered. Lighting industry standards were examined and the in situ measurements were compared to those standards. Standards have changed over the years and the results of the comparisons were mixed. Public records of crash data were used to further inform this research project. This paper begins to fill a gap in the literature regarding empirical case studies of pedestrian and bike path lighting installations.

The factors contributing to crashes, general safety, and security along pedestrian and bike paths include the visibility of the path (i.e. path surface reflectance, lighting type, light level, etc.), and users' demographic factors. To acquire visibility on pedestrian and bike past, even illumination and low uniformity ratios are critical. Prior to the path construction and the new lighting installation, existing light levels measured in-situ in 2005 were found to be very uneven with a maximum to minimum uniformity ratio of 72:1, exceeding the 10:1 uniformity ratio recommendations of both 2000 and 2011. The 2005 light level mean of 4.84 lux was less than 50% of the 2000 recommendation of 10 lux. The 2005 light level mean was 62% of the 2011 recommended 7.8 lux average. Vertical light levels were not recorded in 2005.

After the new lighting was installed, light levels measured in 2012-13 and the light levels were much more even. At less than 10:1, the uniformity ratio at the horizontal and vertical levels 1.53 meters (5'-0): and 1.83 meters (6'-0") above grade complied with both the 2000 and the 2011 IESNA recommendations. This compliance was anticipated to increase visibility and potentially aid safety and security. The 17.11 horizontal lux average measurement exceeded both the 2000 recommendation of 10 lux (70% over recommended) as well as the 2011 recommendation of 7.8 lux (200% over recommended). The 24.33 vertical lux average measurement was more than 11% over the 2000 recommendation of 22 lux but was 900% over the 2011 recommendation of 2.6 lux.

Crash report data were examined for the county, state, and town level. Town level data was only available in the aggregate so trends were not available. Generally, pedestrian and bicycle crashes seem to continue to be a problem for the state, county and town where the study was conducted. Since completion, zero (0) pedestrian or bicycle crashes have been reported along the new path. However, a longitudinal study should be undertaken to determine the number of crashes along the new illuminated bike path.

The vast majority of university student users may be less than 25 years of age in the case of the current project. However, it needs to be considered that many other university and community stakeholders who use the pedestrian and bike path are relatively older. Also, the 39% LRV of the path's pavement was determined to be much lighter than the 0%, 5% and 10% standard choices shown in the IESNA recommendations' worksheet [5]. However, no exacting method was available to acquire a "credit" for the higher reflectance value paving in use.

In the "real-world", lighting design applications are often fraught with compromises. The field of lighting design is very complex. Lighting which some may consider the visual reinforcement of a facility's identity or that which discourages crime, may be considered by others to be wasteful and "unsustainable". The selected pole-mounted, acorn globe light fixtures in the new pedestrian and bike path were accepted to the University and to the Federal funding agency. However, the new light fixtures produce considerable vertical illumination and uplight and this light distribution is contrary to that recommended by the IDA. As indicated by the low SQM readings, 11.3 to 15.3 mags/arcsecond$^2$, relatively poor sky was found at the new pedestrian and bike path (Some sites in less light polluted skies have been measured with quality as high as 20 to 21 mags/arcsecond$^2$.) Although lighting levels measured in 2012 were *initial* levels produced by a new lighting system, the lighting levels measured in the 2005 study in the same area included spill light from aging lighting systems. The *initial* levels will decrease over time, dropping closer to the recommended *maintained* levels. When lighting installations are new, they are at their peak condition – new, very clean lamps and fixtures free from damage and other problems plaguing older systems and eventually diminishing light levels. It is also important to note that published industry recommended lighting levels are designed to be *maintained* rather than *initial* levels.

As a tragic closing note, criminal activity resulted in the ultimate breach in security. At approximately 2:00am, May 19, 2012, a co-ed bicyclist was stalked and subsequently killed by her abductor in the southern town where this case study was performed [11]. Some believe this cyclist was attempting to reach the security of the new illuminated pedestrian and bike path in the current study when the killer's vehicle rammed her bike. There were no eyewitnesses to this criminal event. It is not known if lighting, or lack thereof, was a contributing factor. Law enforcement officers recovered evidence of the co-ed bicyclist and her abductor's struggle in a less-well-illuminated area a mere 408 meters (1338 feet) from the edge of the new pedestrian and bike path. This tragic event underscores the need for more scientific studies to examine whether lighting does increase safety and security along pedestrian and bike paths and to carefully study the thresholds for all lighting attributes and lighting system variables.

Plans for an extension plan of the recently completed pedestrian and bike path, also incorporating new lighting, are underway at this time. The researchers recommend that the new path be designed to meet or exceed current industry safety and security standards. Current users of the path should be surveyed to determine satisfaction, perceptions, use patterns and future needs. A longitudinal study is recommended. Additional studies with geographical variance and with a variety of user and stakeholder demographics; path construction, materials lengths, reflectances and proximities to roadways; traffic levels of nearby roadways, number of dogs in the area, community sizes, crime statistics, lighting sources and corresponding attributes are recommended.

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