Solution Definition and Concept of Operations for: *Nighttime Pedestrian Along Arterials*

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List of Acronyms and Abbreviations

ADLM..............................................................Advanced Lighting Measurement System
CUTR............................................................. Center for Urban Transportation Research
FDOT ................................................................. Florida Department of Transportation
ITS................................................................. Intelligent Transportation Systems
PDL ................................................................. Pedestrian Detection Lighting
SLS................................................................. Smart Lighting System
TECO ............................................................... Tampa Electric Company
1. Introduction

According to Governors Highway Safety Association (GHSA), Florida is ranked 2nd place for total pedestrian fatalities among all states in 2017 and 5th worst when adjusted for the population for first six months of 2017. Eight Florida cities were on the list of top 10 worst pedestrian-friendly cities according to Smart Growth America (SGA).

Nighttime pedestrian crashes are overrepresented on Florida roadway corridors. In 2016, 80% of nighttime pedestrian fatal crashes and 78% of nighttime pedestrian injury crashes occurred on mid-block segments (not intersection-related) (see Fig. 1). It has been identified by many research that poor visibility is the primary factor that contributing to the nighttime pedestrian crashes on corridors. An increase in horizontal illuminance can significantly decrease either expected nighttime crash frequency or expected night-to-day crash ratio on roadways (Wang, et al., 2017). However, the illumination values of street lighting in Tampa Bay area have been found on many roadway locations either below the state standard of illumination level or above the uniformity ratio, which could have serious impact to the pedestrian safety.

There are several questions that needed to be answered for the nighttime pedestrian crashes in terms of illuminance. First, how to accurately, efficiently, and safety measure the illumination values on the roadway? Second, how to maintain the proper level of illumination values on the roadway and enhance the visibility when there are pedestrian movements on the roadway? Third, with limited budgets, what locations should be selected to improve the unqualified lights or install new lights?

In Tampa Bay area, the street lighting system is maintained by Tampa Electric Company (TECO) and City of Tampa. When ITS is implemented to this system, Florida Department of Transportation (FDOT) district level needs to involve in the system to support the implementation of countermeasure for pedestrian nighttime crashes.
1.1 System Overview

To solve the first question, the Advanced Lighting Measurement System (ALMS) developed by Center for Urban Transportation Research (CUTR) team at USF is introduced to measure the illumination values of the roadway. In our proposed system, modified ALMS is developed, which installed on a moving vehicle, can detect the illumination value by 2 points per 10 feet with speed of 30 miles per hour. It can largely reduce the time needed to conduct the measurement and eliminate the safety risk by a conventional method. In addition, the results can be transferred to heat map directly showing the illumination level on the roadway.

The Smart Lighting System (SLS) is developed to monitor the illumination level of street light on the roadway. Light meter sensor is installed on each light pole to detect the illumination level and connected with sensors next to it. Several designated sensors are connected with the control center and information can be transmitted within connected sensors and between the control center and sensors connected to it. The function of control center is to examine each light’s illumination level and give the warning when illumination level is below the required level. In certain hot spots on the corridor with most crash rates, Pedestrian Detection Lighting (PDL) is installed to brighten the lights when pedestrian movement is detected.

With regard to the location for installing new lights and PDL, the illumination data collected from modified ALMS and historical crash rate on the corridor are used to make the decision. A location with high crash rate and low imminence would be apparently regarded as a hot spot, which can obtain the most benefits for pedestrian safety. In addition, modified ALMS is used as an inspection tool to examine the SLS monitor results. There are times that some objects such as tree branches block the light so that SLS cannot detect the real illuminance value on the roadway. Using modified ALMS periodically to examine the SLS ensuring the proper operation.

The ITS equipment should be maintained by the FDOT district level and the lighting system needs to be maintained be TECO and City of Tampa and supported by FDOT district level staff.

2. Referenced Documentation

Additional information regarding the Advanced Lighting Measurement System (ALMS) and intelligent lighting system can be found in the following documents and electronic publications:

3. Current System Situation

Approximately 90% of all street lights in the City of Tampa are maintained by Tampa Electric Company (TECO). Most TECO maintained street lights can be identified by a gray metal band attached to the pole containing a series of number. The approximately 10% of remaining street lights in Tampa are maintained by the City of Tampa. Street lights on bridges or that have yellow tags are typically maintained by the City of Tampa.

Mayor Bob Buckhorn of the city of Tampa announced the Bright Lights, Safe Nights street lighting program in October 2012. The City of Tampa has partnered with Tampa TECO to improve the quality of life in its neighborhoods and business communities. The Bright Lights, Safe Nights street lighting program focus includes:

- The budget of $2.2 million over the next five years
- Installing new street lights at selected locations beginning in Spring 2013
- Targeting locations in zones with high crime or high crash rates.
- Adding approximately 8400 new street lights over the next five years, expanding the current street light network by 30%.
- Monitoring the city-wide inventory of streetlights ensuring the replacement of dimming street lights and the removal of tree branch obstructions
- Keeping our streets and sidewalks safe for our residents and visitors to enjoy

This strategic initiative fulfills Mayor Buckhorn's promise to complete a city-wide lighting inventory to determine where street lights need to be installed, updated, repaired, or replaced. In 2017, FDOT approved new street lighting project that 6 locations around the Hillsborough County will get the LED lighting spots along Fowler, North Nebraska, and West Hillsborough. But it will take time for the $15 million in state safety funding to be put to work.

3.1 Background, Objectives, and Scope

The city of Tampa and Hillsborough County have installed and continue to install new street lights at targeting locations in zones with high crime or high crash rates. However with limited budgets, how to scientifically determine these locations is crucial to the success of implementing these lighting programs. Given that the illumination level of many streets in Tampa Bay area are below the state standard and there have significant correlation between crash rates and street light illumination, allocating new streetlights or improve streets lights in locations that don’t meet the illumination level requirement and have high crash rates will be of most benefit and efficient to
enhance the pedestrian safety. The ability to detect the poorly lit roadways is significant to the allocation of new lights or improvement of existing lights. In addition, automatically adjusting the illumination level when there are pedestrians going across the street has been recognized as an effective countermeasure to improve nighttime safety and reduce nighttime crashes.

3.2 Operational Constraints

The conventional method of measuring roadway illumination involves spot checking along a grid set up in the selected road. The light meter is used to measure the street light illumination by every six inches above the ground. The operator needs to set up the light meter, place it in the middle of the lane, stand back, and trigger a measurement. Then the operator will measure the next point on the grid with the same procedure. This method is not only time consuming, but also has potential safety risk to the operator as the operator has to find a gap between traffic to complete the measurement.

The street lighting is stationary illumination or dimmable street lighting that dims at predetermined times. The more ideal lighting system is the street lighting can adapt to movement by pedestrian and vehicles that the lighting can brighten when movement is detected.

3.3 Description of the Current System or Situation

Most of the streets lights (90%) in the city of Tampa are maintained by TECO and it can be identified by a gray metal band attached to the pole containing a series of number (Fig. 2). A small portion of street lights (10%) are maintained by the city of Tampa and can be identified by yellow tags. They are stationary or dimmable street lighting system that cannot be adjusted by the movement of vehicles or pedestrians.

![Fig. 2 Light tags](image)

The lighting illumination measuring method used is conventional light meter method with time-consuming and high-risk of safety for operators. In some cases, the presence of police and lane closures are used to reduce the dangers of this work but result in additional cost to the measurement process.
3.4 **User Profiles**

Users report a street light out to TECO and city of Tampa. FDOT District level staff is responsible for the measuring roadway illumination.

3.5 **Support Environment**

The lighting system is maintained by TECO and city of Tampa. Roadway illumination measurement is conducted and maintained by FDOT District level staff.

4. **Concepts for the Proposed System**

4.1 **Background, Objectives, and Scope**

The current street lighting systems are not adaptive. They are either on or off without considering traffic volume or pedestrian volume at night. The over-lighted streets waste significant amount of energy. Also, over-aged lights are very dim which contribute to traffic safety and crime issues.

The adaptive lighting or intelligent lighting has become more and more popular among cities. When googling ‘Intelligent lighting system’ or ‘adaptive lighting system’, there has been many companies and researches on this subject and many of them focus on saving electricity of lighting and easier management of light network system. For example, Philips has proposed a lighting system called ‘CityTouch’, it allows cities to flexibly adapt lighting to all kinds of conditions and situations. Its software combined with LED luminaries is expected to reduce 70% of energy. Other companies such as ‘TVILIGHT’, its application can detect vehicles coming and increasing the light for street lights ahead of vehicle so that drivers can get clear view about road condition.

The adaptive lighting system has promising outcome of energy saving. But they are expensive and given limited budget, it is certainly not possible to remove conventional lighting and replace it by intelligent lighting in a large scale. Also as the mid-crossing accident usually happens on roadways where there are very few intersections among a long distance. Those road segments with high accident rate are the focus of project implementation.

The objective is proposing a framework which can

1. Monitor illumination at network level.
2. Evaluate the system through the Modified Advanced Illumination Measurement System (MALMS).
3. Detect pedestrian motion and adjust light illumination

Given high quality illumination, it is expected to reduce the accident at mid-road crossing.
4.2 **Description of the Proposed System**

The system consists of two major parts: Modified Advanced Lighting Measurement System (MALMS) and Smart Lighting System. MALMS detects the street light illumination on a moving vehicle which could eliminate the risks of operators conducting the measurement on the roadway. The smart lighting system is to monitor the lighting illumination and worked as the real-time illumination adaptation based on the pedestrian movement on certain roadway locations. There are times that the lighting sensors on the street lights might not obtain the accurate level of illumination on the roadway as some objects such as tree branches may block the roadway from lighting. MALMS can be used to examine the illumination value obtained from the lighting sensors and conduct the infrastructure maintenance.

The proposed system will be integrated with existing system. It includes three functions: illumination monitoring, illumination examining, and pedestrian movement detection. Monitoring function is to detect and manage illumination at a network level. Examine function is to verify the monitoring accuracy by MALMS. Last function is using adaptive street lighting. Adaptive street lighting can increase illumination level while pedestrian movements are detected. The framework is shown in Fig. 3.

![Fig. 3: Framework of proposed lighting system](image)

Function 1: illumination monitoring
Light meter is installed on each light poll to monitor illumination. It automatically measures and records the illumination level. The sensor will adopt IPv6 internet protocol and form a wireless mesh networks. The recorded illumination is transferred from sensors to sensors and finally to central monitor. Fig. 4 shows its working mechanism.
Each sensor is connected to sensors next to it by wireless communication. If one sensor breaks down, it does not affect the flow of information and the broken sensor can also be detected. This system can evaluate the illumination in real-time. The real-time information is very important since the latest illumination level could best reflect the road driving condition. The light condition reported by sensor is very helpful to evaluate the overall system. However, the real-life travel condition cannot be monitored by the sensor. Sometimes the illumination is good detected by sensor, while the light is blocked by tree. This still could cause uncomfortable driving experience. Thus, the evaluation of real road condition is needed to overcome this issue.

Function 2: illumination examining
Examining is based on the (Advanced Illumination Measurement System) ALMS developed by Center for Urban Transportation Research (CUTR) team. Fig. 5 shows its working process. The light sensors are mounted on a vehicle. When vehicle speed is lower than 40 mph, it can automatically collect horizontal illumination and vertical illumination accurately. It collects two light illumination points per 10 feet.
The data recorded by ALMS can be presented in ArcGIS manually. This is however not ‘intelligent’ enough. It needs to be modified so that the recorded data could be directly displayed on screen. Image driving along the road, the illumination is recorded and automatically presented on the map. The areas without enough of light are highlighted. It is a fast process and quickly reporting any issues that might not be discovered by sensor network. Thus, our framework will use Modified ALMS (MALMS).

Function 3: Pedestrian movement detection
The research released by CUTR has shown that illumination has correlation with mid-crossing pedestrian accidents. Some hot accident spots could be identified by traffic accident location data. The pedestrian detection lighting is an adaptive street lighting system. It integrates the sensor which could detect the pedestrian motion and adjust the illumination level. When a pedestrian passes the lighting and captured by sensor, the illumination level will increase so that pedestrian can be better seen by drivers.

The lighting will be installed at places where pedestrian accidents happen most. The sensor will adopt IPv6 internet protocol and communicate with light monitor sensors nearby. This will transmit its information to central controller.
4.3 Modes of Operation

In case of sensor network break down, the MALMS can still be operated to detect issues of dim light. There shall be more than 1 modified MALMS device. If one breaks down, back up device could be used. If pedestrian detection lighting breaks down, it is essential to repair the lighting as quick as possible and warnings shall be placed to slow down vehicle speed.

4.4 User Involvement and Interaction

FDOT, TECO, and City of Tampa are the users of this lighting system. The sensor manager and MALMS operator shall work together to identify potential issues of dim light and improve pedestrian safety.

4.5 Support Environment

The whole sensor system and pedestrian detection lighting will be installed and maintained by Tampa Electric Company (TECO). TECO might contract with factories to purchase the sensor and maintain it. The MALMS will be supported by CUTR staff. They might further update the equipment so the data collection and visualization could be faster and more accurate.

5. Operational Scenarios

This section describes how the proposed light system could be applied in practice through a specific road segment presentation. Fig. 6 shows a case of night time crash and its correlation with light illuminance at a principle arterial during year 2015 to 2016 in Tampa, Florida. The figure was created by CUTR combining ALMS data and night time pedestrian accident data.

From the figure, roughly four hot spots are identified where pedestrian accidents happened most frequently (show in figure marked by red circle). They are either at darkest position or places where illumination level changes. Especially when light turns bright to dark, drivers will take time to adapt the light condition. Thus, four pedestrian detection lightings will be installed in these locations to increase illumination level. This will help drivers to see pedestrians more clearly. Other than that, the light sensor shall be installed for all street lights in this road segments. The central monitor shall be able to monitor the illumination level for these lights. Modified ALMS shall be dispatched once a week to evaluate the real lighting condition along the road.
Fig. 6 Nighttime crash and light illuminance level (source: CUTR)
6. Summary of Impacts

The primary advantage of the proposed system in this document is to help reduce nighttime pedestrian crashes and improve the street lighting system to produce the most benefits. The current system provides stationary lighting and cannot detect the pedestrian movement. The SLS is capable of monitoring the illumination level of lights and detect the pedestrian movement. It provides extra lighting for pedestrian movements in hot spots and keeps illumination at the proper value and uniformity, thus reduces the crash rate in both vehicles and pedestrians. Although the City of Tampa has implemented the Safe Nights Street Lighting program to install new street lights, the locations they chose is based on the crash rate and crime rate, which not necessarily bring greatest benefits to the pedestrian safety. In our system, besides crash rate, lighting illumination level and illumination uniformity are also considered to determine the location of new lights, which could produce more safety benefits for pedestrians. The modified ALMS provides more efficient, safer, and less cost measurement method for illumination detection work.