2. DESIGN REQUIREMENTS/CONSTRAINTS

In order to protect pedestrian lives, our team has developed the Smart Crosswalk Dynamic Lighting System (SCDLS). By using LED lighting, this system could prevent pedestrian fatalities due to motorist/pedestrian collisions that occur in crosswalks. SCDLS is a system that consists of multiple modules installed on both sides of a crosswalk that will light a path for pedestrians while alerting oncoming motorist of the pedestrian using flashing lights when in use. There are two different types of modules used in SCDLS: nodes and hubs. The nodes are the basic makeup of the system and consist of a battery, a wireless module, a solar panel, and LEDs. Hubs are nodes with the addition of pedestrian sensors and Wi-Fi modules and are installed on the edges of the crosswalk. The modules will be in communication with one another not only to light the nodes but also to record traffic data. The hubs will have a sensing range limit for each other, the pedestrian, and the motorist. In order to create the most efficient and effective sensors for the crosswalk, SCDLS is intended to be used on crosswalks for two lane roads. In designing, developing, and producing SCDLS, there are technical design constraints and the practical design constraints that both give SCDLS its' functionality and its consumer acceptability. The technical and practical constrains are outlined in table 2.1 and 2.2 respectively.

2.1. Technical Design Constraints

Table 2.1. Technical Design Constraints

Name	Description
Power Sustainability	The solar panel should sustain the battery and other circuitry for at least 5 years.
Ingress Protection	The hubs and nodes must meet the solid and liquid ingress protection as defined by IP-67.
Compressive Strength	The hubs and nodes must be able to withstand a 6000lb compressive load as defined by ASTM-D4280-12.
Transmission Distance	The hubs must be able to communicate with the other hubs/modules at a distance of 10 meters.
Software Functionality	The system must be able to upload traffic metrics to a server when the hubs are in range of a Wi-Fi network.

2.1.1. Power Sustainability

Power sustainability is important for the function of this product because the expected life is 5 years. If the battery voltage or state of charge drops too low the battery could be damaged, and the product will be unable to function properly. Since the product needs to be rapidly developed, the power sustainability will be modeled based on data gathered from the system rather than installing the system and waiting five years for it to fail. In order to properly model this system data will be gathered about the cumulative energy input to the battery from the solar panel and the cumulative power output from the battery. Considering the unpredictable nature of solar power generation data must be gathered that is representative of a typical year's sunlight. This data will be used in coordination with battery state of charge (SOC) data to determine if energy stored within the battery will ever be below the low voltage shutoff point within five years. In order to account for the varying levels of sunlight in the areas in which this product could possibly be used, a safety factor will be added.

2.1.2. Ingress Protection

Due to the varying conditions that a modern road faces, SCDLS will need to be protected against adverse environmental conditions. In the event that SCDLS is installed in a dusty area or on a road that has poor drainage the system needs to be robust. The Ingress Protection (IP) level selected for this project is IP-67. This level of protection indicates that the modules are completely dust tight, and can be immersed in up to 1 m of water for 30 minutes.

2.1.3. Compressive Strength

SCDLS will be installed on roads that consistently see automotive traffic, so they need to be designed to withstand the impact of an automobile's tire. This product will be designed in accordance with the American Society for Testing and Materials (ASTM) standard for Standard Specification for Extended Life Type, Nonplowable, Raised Retroreflective Pavement Markers, D4280-12. This standard outlines tests that can be performed to validate the strength and anticipated durability of devices applied to road surfaces. This standard is generally intended for purely reflective road markings, but SCDLS is identical in application and loads faced. This standard requires placing the device under test (DUT) in a compression testing apparatus that consists of 13-mm (0.5-in) thick steel plates that are larger than the DUT on the top and bottom. Before performing the test, SCDLS modules will be conditioned at 23.0° C for 4 hours prior to conducting the test. The test will be considered successful if the unit does not break or deform more than 3.3 mm as defined by D4280-12 [1]. This testing will be performed at the Center for Advanced Vehicular Systems (CAVS) or at Future Labs, LLC.

2.1.4. Transmission Distance

For acceptable performance of the crosswalk the modules need to be able to communicate at a distance of at least 10 meters. This is significant because a two lane road can be up to 24 feet wide [2]. This gives our team a safety margin of 9 feet in the event of adverse weather conditions or interference due to other sources. This will be tested utilizing the wireless modules and a metal enclosure similar to one that will be used in the final product.

2.1.5. Software Functionality

For the product to be successful it must be able to upload traffic metrics when in range of a wifi network. This will be supported by software by having a systematic method for connecting to a wifi network, finding a server and uploading traffic statistics. This will be tested by letting the hub upload gathered data and then verifying that the correct data is uploaded.

2.2. Practical Design Constraints

The following design constraints are less technical in nature than the ones given above. These focus on the system's market appeal, overall safety, and cost. They are therefore equally critical to the success of the SCDLS system.

Table 2.2. Practical Design Constraints

Type	Name	Description
Economic	Cost	The expected retail price for this system is $3000. This is based on a projected parts cost of $1000 (for a two-lane system). The system must be able to be installed without modifying existing roads.
Sustainability	Reliability	The system should operate over a five-year period without failure.
Manufacturability	Case Material	The final product's case will be made out of an aluminum alloy. The product will be enclosed using a waterproof epoxy sealant.
Health and Safety	Safety	In order to reduce the product's tripping hazard, the devices' cases will contain no sharp edges. The devices will be designed to prevent the likelihood of automotive tire damage.
Sustainability	Maintenance	If a module is damaged or if upgrades are made, new modules must be able to be easily integrated into the existing device network, requiring no changes to the existing nodes.

2.2.1. Cost (*Economic*)

The SCDLS system is designed to compete in a market occupied by other traffic safety and analysis systems, several of which are detailed above in the Problem Statement section. Therefore, the system must be substantially less expensive, in terms of both its installation and upkeep costs and of its actual purchase price.

Because of the design of the SCDLS system, the SCDLS installation and upkeep costs should already be much smaller than those of competitors' offerings. Many competing products require the installer to modify the road by cutting trenches for power cables or installing sensor towers. SCDLS should require no such modifications. The only installation the modules should require is affixing them to the road with a suitable adhesive, in addition to a one-time software configuration. This constraint should ensure that SCDLS is easy to deploy in nearly all crosswalks.

The target retail cost of an entire two-lane system is $3000. This cost is based on a projected per-module materials cost of around $150 per hub and $100 per node. A two-lane system should have eight modules, including two hubs. This cost is broken down based on preliminary component pricing research, as follows:

Component	Cost for Hub	Cost for Node
PCB	$20	$20
Passive components	$2	$2

Microcontroller	\$3	\$3
LEDs	\$5	\$5
Solar	\$10	\$10
Battery	\$15	\$15
Solar panel	\$15	\$15
2.4GHz module	\$4	\$4
Wi-Fi module	\$4	
Pedestrian sensors	\$34	
Case materials	\$40	\$35
Total cost per unit	**\$152**	**\$109**

Of the above costs, the pricing for the case is the most uncertain, but the overall cost estimate provides a good target based on competitors' offerings.

2.2.2. Reliability (*Sustainability*)

The SCDLS system is designed as a long-term, low-maintenance solution for crosswalk lighting. To that end, the system should last a reasonable amount of time before requiring replacement. Because the system is highly modular, failure of one component should affect the operation of other components as little as possible. For example, if one of the hubs fails, the other hub(s) must continue to detect pedestrians to the best of its ability.

Individual modules should also be designed in such a way that they will last several years on the road. There are limiting factors to the devices' longevity: the batteries in each module will gradually lose capacity, and abuse from vehicles will wear out the waterproofing and physical case. Therefore, considering the relatively low cost of the SCDLS system and the low maintenance costs, individual modules should have a lifespan of several years, with the overall system having a lifespan of five years.

2.2.3. Case Material (*Manufacturability*)

Because of the mechanical restrictions outlined in the Technical Design Constraints section, the case must be manufactured out of a sturdy material that is capable of withstanding years of abuse by automobiles and weather. In addition, the material must be affordable enough to meet the target retail price given above. To best meet these restrictions, the case should be machined from an aluminum alloy. Aluminum handles compressive loads well, is corrosion resistant and is easy to machine.

Because of the nature of its application, the SCDLS system must operate for extended periods of time in potentially wet environments. Although the aluminum case will not be affected by water, the internal components must remain sealed from moisture. Therefore, the open edges on the modules (for example, where the solar panel meets the case) will be sealed with a waterproof epoxy. This seal must remain intact throughout the expected life of the product.

2.2.4. Safety (*Health and Safety*)

Because the system will be installed in an area with high foot traffic, the product must not be a tripping hazard. Pedestrians, especially distracted ones, will not be paying much attention to the edges of the crosswalk. The modules must be sized and shaped in a way that minimizes the tripping hazard the modules pose to pedestrians.

The modules will also be subjected to vehicle traffic. Any obstruction on the road, including SCDLS modules, could potentially puncture vehicle tires, especially if they are shaped improperly. Because drivers cannot easily steer around the modules, the modules must also be designed to minimize the danger they pose to vehicles' tires.

2.2.5. Maintenance (*Sustainability*)

One of the SCDLS system's goals is to minimize the expenses associated with making crosswalks safer. To this end, the system should not require active maintenance to modules which have been installed. Furthermore, because the system is highly modular, the failure of one device should not require the replacement of the other devices. Instead, the replacement device should be able to begin communicating with the other modules. Therefore, in the event that a module fails, a faulty device should be able to be replaced without having to replace or modify the other working modules.

WORKS CITED

[1] Federal Highway Administration, "Lane Width," 15 October 2014. [Online]. Available: http://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter3/3_lanewidth.cfm. [Accessed 17 February 2015].

[2] ASTM International, "Standard Specifications for Extended Life Type, Nonplowable, Raised Retroreflective Pavement Markers," 2012. [Online]. Available: http://www.astm.org/Standards/D4280.htm. [Accessed 17 February 2015].