COVER PAGE

Title of Design: Evaluation of Airfield Lighting Efficiency at Columbia Regional Airport

Design Challenge addressed: Airport Environmental Interactions

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LED Efficiency Design for Medium Capacity Airports

15 April 2011

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Executive Summary

Summary: During recent economic turbulence, airports have been struggling to stay in the black. Specifically, medium-size airports have struggled recently with respect to passenger demand. With approximately 45 medium-sized commercial airports in the United States, there is a great need for energy sustainability to power future growth. Through innovative efficiency studies, these medium-capacity airports can start to grow again. Light emitting diode (LED) technology is currently the most efficient rival to traditional incandescent lamps. These LEDs are currently approved for replacing incandescent taxiway lighting, and other LED lighting awaits FAA approval. In order to understand how much money can be saved by investing in LED technology, a case study of Columbia Regional Airport (COU) was performed. This case study provides much needed evidence not only for COU, but for all medium-size airports with respect to fixture efficiency. Using data provided by COU and advice from airport engineering experts, LED technology is shown to be the best option for medium capacity airports. Almost all of COU incandescent lighting fixtures can be replaced now or in the near future with LED fixtures. Even though fixture replacement will bring significant initial costs, these costs will be repaid quickly because of greater energy savings. Based on estimates, if all runway and taxiway lights are replaced, these initial costs could be repaid in about 3 years. Most of the savings would come from reduced labor and lamp replacement costs. Acknowledging that higher initial costs might deter some airports to install LEDs, savings of almost $34,000 per year was estimated for COU, which would provide medium-capacity airports extra capital for other improvement projects.

Table of Contents

I. Problem Statement and Background 1

A. Problem Statement 1

B. Background 2

II. Summary of Literature 2

A. Current Federal Aviation Administration (FAA) Guidelines 2

B. Alternative Lighting Technology 4

C. Case Study 5

D. Columbia Regional Airport 7

III. Problem Solving Approach to Design Problem 9

IV. Safety Risk Assessment 10

V. Technical Aspects 12

B. Sulfur-Plasma 13

VI. Interactions with Airport Industry Experts 14

VII. Projected Impacts 16

VIII. Conclusions 19

Appendix A: List of Complete Contact Information 20

Appendix B: Description of the University of Missouri 21

Appendix C: Description of Non-University Partners Involved With The Project 22

Appendix D: Design Submission Form 23

Appendix E: Evaluation of the Educational Experience Provided By the Project 24

Appendix F: Reference List 27

Table of Figures

Figure 1. Alternative LED Mounting Method 4

Figure 2. Pre- and Post- Retrofit of Sulfur Plasma Lighting 6

Figure 3 Aerial of Columbia Regional Airport 7

Figure 4 FAA Risk Matrix 11

Figure 5. Existing Outdoor Lighting at COU 14

Figure 6. Introduction to Airport Engineering Lecture 14

Figure 7 COU Suggested Lighting Replacement 17

Figure 8 University of Missouri, Francis Quadrangle 21

I. Problem Statement and Background

A. Problem Statement

Throughout its history, Columbia Regional Airport (COU) has been burdened by increasing financial costs. Rising energy costs are among the major expenses the airport must tackle in the near future. Through the use of new "green" technology, COU can improve the quality, efficiency and environmental sustainability of runway illumination. By implementing a new lighting program, COU could potentially reduce maintenance time and cost, while improving safety. By researching other relevant cases, COU can incorporate improved methods to meet its unique needs. Studying alternative energy lighting methods, COU can take advantage of these methods, even if the technology is not cost-effective currently. As these technologies gain wider acceptance leading to economies of scale, these methods could be cost-effective in the future for COU as well as other medium capacity airports across the United States.

In addition to cost savings, airports are facing additional compliance issues. Due to "The Energy Independence and Security Act of 2007", airports must begin to switch from incandescent lamps by 2014. Under current law, the Department of Energy (DOE) is required to design a replacement for the PAR Type 38 halogen light, which will be a light emitting diode (LED) lamp. This example further promotes the study of implementing alternative lamps (e.g. LED lamps), which can provide cash-strapped airports an opportunity for savings. In addition, this law required the replacement of these wasteful incandescent lighting systems, a further reason for the proposed design (Gallagher & Williams, 2009).

B. Background

COU began operation in 1928 when it was leased from the Allton Brothers. With some alterations, the land was then used for emergency landings between Kansas City, Missouri and St. Louis, Missouri. This airport was in a different location than the current airport, and was small that it necessitated an expansion. Expansion of that particular site proved too costly. After several new locations were investigated, a site off of Highway H was chosen. This was very effective because the original airport was far enough away that it could still support operations while the new airport was being constructed, thus not losing money from having to shut down. It took about six years from the time the new location was suggested to the actual opening of the airport, from 1963 to 1969 With anticipated continual growth of the airport, the need for cost reductions is great (Reynolds, Smith, and Hills, Inc., 2009).

II. Summary of Literature

A. Current Federal Aviation Administration (FAA) Guidelines

The main source of information for basic airport design is based on FAA Advisory Circular (AC) 150/5300-13, which is titled “Airport Design,” and was published in 1989. Airport runway lighting guidelines are found in Chapter 6: “Site Requirements for NAVAID and ATC Facilities.” This chapter thoroughly describes NAVAID (Navigational Aid), which comprises electronic and visual navigation. Visual navigation is the applicable topic here (Federal Aviation Administration, 1989).

The proposed design focuses on runway approach lighting only. Specified in Chapter 6, an airport landing system (ALS) is available to “augment” the NAVAID system. Therefore, the

ALS is specifically maintained to help pilots navigate, in addition to their electronic equipment. The ALS is a critical piece of the runway safety system The FAA currently approves four different sets of ALS for different airport conditions. The four approaches are: Approach Lighting with Sequenced Flashers 2 (ALSF-2), Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights (MALSR), Medium Intensity Approach Lighting System (MALS), and Medium Intensity Approach Lighting System with Sequenced Flashers (MALSF) (Federal Aviation Administration, 1989).

The ALSF-2 system requires an over 2,000-foot long high-intensity lighting system which incorporates sequenced flashing lights. In addition, the ALSF-2 system is currently mandated for Category (CAT) II and CAT III precision approaches. Next, the MALSR system requires an over 2,000 foot medium intensity ALS, but must include runway alignment indicator lights (RAILs). The FAA has approved this system as an "economy" ALS system, but only for CAT I approaches. Specifically, the MALS section of the MALSR is only 1,400 feet in length, and the RAIL section extends 1,000 feet out. The next system, MALS, requires a 1,400 foot medium intensity lighting system. However, this system is for non-precision instrument or night approaches; whereas, the previously mentioned approaches were mandated for precision approaches only. The final system, MALSF, requires a medium intensity lighting system which is indistinguishable from the MALS system except that flashing lights are added to the outer bars. These flashing lights will help distinguish the airport from other lights in the area (i.e. major city airport). However, for the purposes of this research paper, only elevated runway and taxiway edge lighting will be considered in detail as this matches COU's current ALS for the airfield (Federal Aviation Administration, 1989).

B. Alternative Lighting Technology

One source of potential replacement lighting is LED technology. These semi-conducting light sources are able to produce high luminosity while requiring significantly less energy than standard incandescent lighting currently used at many airports. As mentioned by the Lighting Research Center, most incandescent lighting requires 30 watts per fixture. By switching just the taxiway fixtures to LED, it is estimated that 50 million kilowatt-hours (kw-h) could be saved on electricity. LED technology promotes energy efficiency; however, this efficiency causes heating issues during cold weather. During winter, LEDs do not produce enough heat, like incandescent fixtures, to melt snow outright. This either requires the use of heaters with each LED fixture or the use of an experimental fixture to utilize all the heat produced by the LED. A typical use of LEDs incorporates the standard fixture arrangement that was used by incandescent lighting. This set-up however does not efficiently use the heat produced, and does not meet the FAA requirements for ambient operating temperatures. Figure 1 shows an example of a modified fixture. With the use of additional heaters, any electrical reduction from the more efficient lighting is essentially neglected (Gu, Baker, & Narendran, 2007).

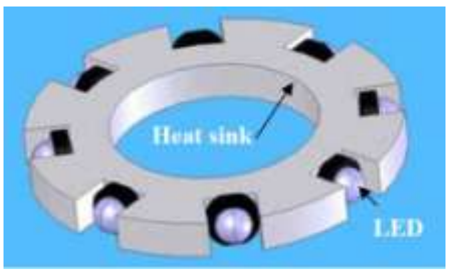

Figure 1. Alternative LED Mounting Method

An additional option for replacement lighting is sulfur plasma lighting technology. Products using sulfur plasma are relatively new to the market, and are still in testing or experimental phases. With plasma lighting, the light source tends to use more energy than most incandescent lighting. Due to the extreme brightness of the light source, the quantity of bulbs can be reduced, which can potentially reduce overall electrical costs. This application would work with airplane hangars, parking lots, and where runways need spotlights. Another advantage of plasma lighting over incandescent is that plasma lights produce a larger spectrum of visible wavelengths which helps to improve visibility and clarity (Plasma International , 2009).

C. Case Study

In order to validate the effectiveness of the available alternative light sources, case studies could be used. In a case study conducted by the Lighting Research Center, standard incandescent taxiway lights were replaced with blue LEDs (Gu, Baker, & Narendran, 2007). Typical photopic transmission value or amount of light transmitted under well-lit conditions, for incandescent lighting was around 5% while blue LEDs achieved a photopic transmission of over 82%. In other words, a blue LED light can produce more wavelengths that are picked up by the eye than a typical incandescent light source, thereby making the light appear brighter. This also demonstrates that less electricity is needed when using LEDs. Approximately 50 million kilowatt hours could be saved in the United States (US) if all taxiway fixtures were converted to LEDs. A challenge to this study involved meeting FAA regulations for weatherability, which requires taxiway fixtures meet performance criteria at ambient temperatures ranging from -40 degrees to 55 degrees Celsius. In order to meet the requirement, a LED fixture must be able to increase its ambient temperature enough to reach the melting point of ice (0 degrees). Lab tests demonstrated that the typical set-up for LED will not allow this temperature increase; therefore, an additional heat source must be included with each fixture. This addition essentially eliminates any energy savings that may have been gained from changing to LEDs. Through modification of the glass dome used to house LEDs, taxiway light fixtures will utilize all of the light source's heat output. This change allows the lamp to meet the FAA criteria for weatherability (Gu, Baker, & Narendran, 2007).

Another case study was performed by the Pacific Northwest National Laboratory demonstrating and assessing a sulfur lamp retrofit lighting system (Richman, Heerwagen, & Hollomon, 1998). Using a 284,000 ft^2 area located in a hangar at Hill Air Force Base in Utah, the study consisted of using 288 sulfur-plasma lamps, 88 of which were used at the ends of 44 tubular light guides extending 104 feet each. Figure 2 shows before and after pictures of the hangar being retrofitted with sulfur-plasma lamps. Using collected data from the previous lighting arrangement and the new sulfur retrofit, the test demonstrated the abilities of this relatively new light source. Lighting levels increased upwards of 160 percent, and workers were able to see more detail. Improved clarity was due to the increased spectrum of wavelengths produced by sulfur-plasma lighting. When energy consumption was measured, the new retrofit actually consumed 63 percent more energy in non-tubular lighting. This was possibly an effect of using preexisting fixtures which prevented optimum placement of each individual lights. In addition, the previous light sources did not create enough luminosity as needed for the hangar, thus the comparison of energy was also not accurate. Estimates of energy consumption using correct fixture placement for the sulfur alternative show a reduction of up to 37 percent may have occurred.

Figure 2. Pre- and Post- Retrofit of Sulfur Plasma Lighting

D. Columbia Regional Airport

COU currently has two runways, 02/20 and 13/31(Figure 3). Runway 02/20 is 150 feet wide and 6,500 feet in length; it is the primary runway. The runway surface material is concrete and the surface treatment is grooved. According to the FAA, this runway has a single-wheel load rating of 92,000 pounds, a dual-wheel load rating of 125,000 pounds, and a dual-tandem wheel load rating of 215,000 pounds. Runway 13/31 is 75 feet wide and 4,401 feet in length; it is the crosswind runway. The surface material is asphalt. According to the FAA, this runway has a single wheel load rating of 21,000 pounds and a dual-wheel load rating of 24,000 pounds. The primary runway can be used by several large aircrafts such as Boeing 737s, McDonnell Douglas DC-9s, and McDonnell Douglas MD-80 aircrafts. The primary runway (02) is the only precision runway (Reynolds, Smith, and Hills, Inc., 2009).

Figure 3 Aerial of Columbia Regional Airport

Runway 02/20 operates a High Intensity Runway Lighting (HIRL) system. Runway 02 uses Instrument Landing System (ILS), Medium-intensity Approach Lighting system with Runway Alignment Indicator Lights (MALSR), and a Localizer (LOC). Runway 20 uses Omni-Directional Approach Lighting Systems (ODALS), Runway End Indicator Lights (REIL), and a Visual Approach Slope Indicator (VASI). Runway 13/31 operates a Medium Intensity Runway Lighting System (MIRL) using REIL and VASI (Reynolds, Smith, and Hills, Inc., 2009).

COU has three taxiways, A, B, and B-2. Taxiway A is parallel to runway 02/20, taxiway B is parallel to runway 13/31, and taxiway B-2 is the access to the hangars. All the taxiways have Medium Intensity Taxiway Lights (MITL). The apron areas are also lighted by several 1000 watt metallic vapor lamps on 38-foot poles. (Reynolds, Smith, and Hills, Inc., 2009)

COU has one airport beacon, used by pilots to locate the airport at night or in unfavorable weather situations. This beacon is situated on top of a 50 foot pole, which is 500 feet west of the terminal building. It projects two rotating beams of light, green and white, at 10,000 watts. COU could benefit from increased light savings, because COU has many lights that are required for taxiways and runways. (Reynolds, Smith, and Hills, Inc., 2009)

As previously stated, COU currently employs the MALSR system. The FAA states that a MALSR incorporates 18 lamps, which are located along the runway threshold. These lamps, PAR 56, are spaced every 10 feet. The goal of the MALSR system is to provide a planned approach visibility between 1800 feet to 2640 feet. According to FAA documents, the MALSR system has been evaluated using both incandescent and LED lamps, and concluded that replacement LED lamps are very cost-effective. In June 2010, the FAA awarded a contract that will study a sample implementation of LED lamps. This example clearly shows the FAA's commitment to runway lighting energy efficiency. Finally, the FAA released a report on replacing PAR 56 incandescent lamps with LED lamps that concluded that there was considerable benefit in replacing incandescent lamps with LEDs. The agency later stated that potential energy savings could repay for the new equipment costs in about two years. This study confirmed that LED technology is a sustainable replacement for current incandescent lamps. Implementation of these new-generation lamps will allow airports to achieve great savings in a time of economic uncertainty (Federal Aviation Administration, 2010).

III. Problem Solving Approach to Design Problem

When presented with the task of researching and presenting a solution to problems many airports must deal with on a daily basis, our team immediately realized the importance of energy efficiency in today's market. As with many businesses, airports face the constant struggle to find areas in which expenses can be reduced. The team recognized the direct correlation that can exist between cost reductions and energy efficiency as a viable option for many airports. By focusing on the airfield lighting components specifically, the team hoped to find improvements that could apply to a broad range of airports at reducing overall expenses. In order to make the topic selection more relevant to the team, a case study of a nearby airport, COU, was chosen. This allowed the team to work with airport officials in determining how energy efficiency could be improved at COU and provide specific conclusions in redesigning the airfield lighting. By performing a case study on COU, the team could assume similar applications would apply to other medium-sized airports.

The team consisted of three undergraduate students with a faculty advisor. In order to optimize time and efficiency, the team worked together to narrow down potential topics and outline objectives and goals. Upon finalization of a main topic, the team decided to designate specific tasks to each student. Tasks included contacting professional experts, researching energy efficiency, costs of alternative light sources, determining FAA runway lighting requirements, and research of the existing light usage at COU. Subdividing tasks helped reduce the overall work load while allowing each team member to become knowledgeable on specific aspects of the design report.

In order to ensure relevance of the design topic, contact was made with multiple sources to confirm research findings and their application to COU. The team met with employees from

COU, including Gregory Cecil, to determine the applicability of alternative lighting options. A field check was performed at the airport to gain a better understanding of the existing lighting configuration. With this knowledge, the team was able to find exact lighting replacements using LEDs as discussed under “Projected Impacts”.

IV. Safety Risk Assessment

Before changes to a system can be made, all the hazards must be addressed. The formal process for this is called Safety Risk Management (SRM). This process has five phases: describe the system, identify the hazards, determine the risk, assess and analyze the risk, and finally treat the risk, which are located in the FAA Safety Management System Manual (2004).

For the proposed plan to install LED lighting on the runways and taxiways of COU there are some obvious safety risks, all of which stem from the actual task of installation. By definition, a safety assessment is a “systematic, comprehensive evaluation of an implemented system.” (Federal Aviation Administration, 2007). Keeping this in mind, the team attempted to thoroughly analyze all potential safety concerns with implementing LED lighting fixtures. There are also some safety risks that were not expected, such as the effect of LEDs on eyes, or the brightness of the LEDs decreasing the ability for a pilot to take off or land a plane with the same amount of accuracy as with incandescent.

When installing new lighting on a runway, the runway becomes unusable and planes are forced to use other runways, when conditions may not be ideal for that particular runway. Also, people and equipment on a runway brings a whole host of safety risks for people in the planes and people on the ground. Equipment could get left on the runway, or a person could be unaware of a plane taking off or landing and be on the runway at an importune time.

Another safety risk posed by the implementation of LED lighting is an eye health risk. A study concluded that royal blue and blue (450-485 nm dominant wave length) LED lamps pose a higher safety hazard than white LEDs (CREE, Inc., 2010). Other colors, like red and green, do not pose an eye safety risk. The report also says explicitly that regardless of LED color, users should not look directly at any LED lamp. So any blue LED lighting included on the airfield would be a possible safety risk, but not significant enough to stop the installation of LEDs.

The likelihood of the LEDs being so bright that pilots have difficulty taking off and landing is very small. The severity of this risk, however, is significant. This risk could result in a crash landing or crash while taking off, injuring or killing the people on the plane. Figure 4 was used when estimating risk (Federal Aviation Administration, 2004). The likelihood the LEDs would have a harmful effect on the eyes is also very small, and so is the severity, so this risk is not of great concern. Lastly, the severity and likelihood of someone being injured while working on the lights on the runways and taxiways is more likely and severe.

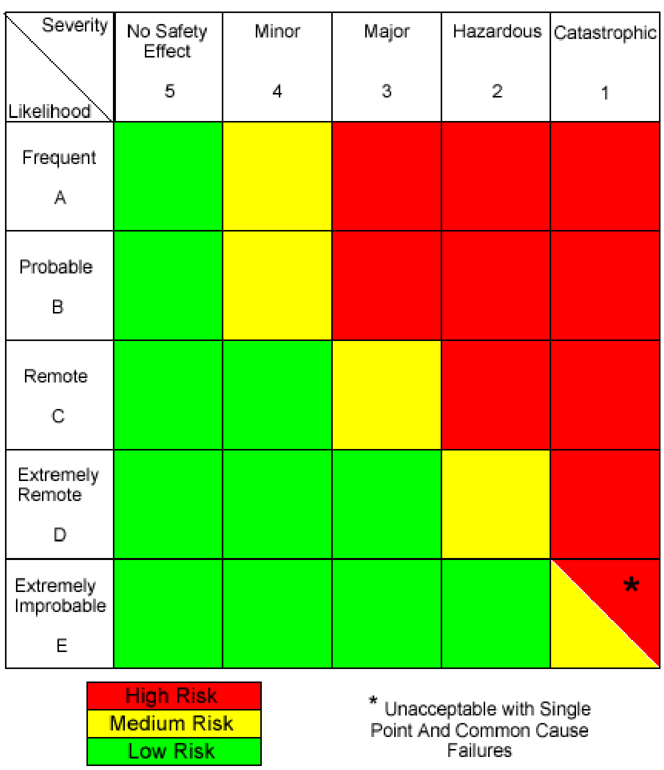

Figure 4 FAA Risk Matrix

To treat these risks, no one should look directly into the lights once they have been turned on. All pilots will be warned of how bright the edge lighting is so they can be prepared and hopefully their vision will not be impaired. Lastly, while people are on the runway at night to install the new lights they must be very careful and aware of their surroundings. One runway or taxiway will be shut down at a time and the one that is not operational will be having the LEDs installed. Workers must have a method of communication with the tower so they know when a plane is taking off or landing so they will be prepared and accidents can be avoided.

V. Technical Aspects

A. LED Lighting

Through contact with multiple sources from COU, the team learned of a major supplier for LED technology in the airfield industry. ADB Airfield Solutions provides an assortment of FAA approved lights for implementation at any airport (2010). Table 1 lists the various light sources that are implemented at COU and if is there any equivalent LED options. Table 1 shows that 11 out of the 17 lights have the LED option available. The possible options for replacement lights include elevated taxiway edge lights, elevated runway edge lights, and elevated runway threshold lights. These three options make up the majority of lights present at the airfield thereby ensuring the long term cost-savings through implementation of LED substitutes. As discussed in "Project Impacts", this design focuses only on the existing elevated taxiway and runway edge lights at COU.

Table 1. Existing Light Models at COU

Description	Model Number	LED Option
Medium-Intensity Elevated Taxiway Edge Light	L-861T	Yes
Obstruction Light	L-810	Yes
Metal-Halide Beacons	L-801A or L-802A	No
Information Sign	L-858Y/L	Yes
Mandatory Sign	L-858R	Yes
Elevated Runway Guard Light	L-804	Yes
Illuminated Windcone Non-Frangible	L-807	Yes
Illuminated Windcone Frangible	L-806	Yes
Elevated PAR-56 Medium-Intensity Steady Burning Approach Light		No
MALSR Medium-Intensity Elevated Flasher System		No
PAR-38 MALSR Steady Burning Medium-Intensity Approach Light		No
Medium-Intensity Elevated Runway Threshold/End Light	L-861E, L-850D, L-850E, L-861E	Yes
Precision Approach Path Indicator	L-880	No
Runway Distance Remaining Sign	L-858B	Yes
Medium-Intensity Elevated Runway Edge Light	L-861	Yes
High-Intensity Elevated Runway Edge Light	L-862	Yes
ALSF High-Intensity Elevated Flashing Light		No

B. Sulfur-Plasma

While the main focus of performing a case study with Columbia Regional Airport is to demonstrate the effectiveness and energy savings that can be provided through replacement of existing runway and taxiway lighting with LEDs for mid-sized airports, additional energy efficiency can be accumulated through replacement of other light sources. Upon performing a field check of COU, it was noticed the large number of street lights in use for parking lots and outside building lighting. Figure 5 shows an example of the lighting surround all buildings on the airfield. These lighting sources could potentially be replaced with experimental sulfur-plasma lamps such as those provided by Plasma International (2009). Although lamps such as these require larger amounts of electricity to operate (as discussed in section II.D.), the increased light output could result in a reduction in the number of fixtures required for optimum lighting. In order to validate this claim however, a separate case study would need to be performed analyzing the existing lighting systems used, retrofit costs, and estimated cost-savings. The scope of this report is restricted to a case study of LEDs in COU.

Figure 5. Existing Outdoor Lighting at COU

VI. Interactions with Airport Industry Experts

On October 09, 2010 Mr. Greg Cecil gave a presentation to the Airport Engineering class, which discussed COU. Greg Cecil is currently the Chairman of the COU Advisory Board (Cecil, 2010). He spoke about the history of the airport, and its current condition as a regional airport. COU was recently removed from FAA Essential Air Service in August 2010 because of improved performance (Cecil, 2010). Delta has been providing non-stop service to Memphis since 2008 and has also upgraded to 50 seat regional jets (Cecil, 2010). Thus, Columbia Regional is currently finding new ways to make (or save) more money and to provide better service to passengers. Mr. Cecil said that LED fixtures had the potential to offer a significant return on investment, which is a key

Figure 6. Introduction to Airport Engineering Lecture

for medium-sized airports, like COU, to remain competitive with larger metropolitan airports (Cecil, 2010). In fact, with COU looking to expand in the near future, LED lighting upgrades could be included in addition to other major plans (Cecil, 2010).

David Sparks, P.E. from Kimley-Horn and Associates spoke to the Airport Engineering class on October 19, 2010. Mr. Sparkes presented on the airport design and construction of Runway 9-27 in Memphis-Shelby County Airport. The presentation discussed design and construction issues during a runway redesign. Mr. Sparkes was insistent that LED lighting was growing throughout airports in the United States. He stated that many airports were considering switching to LED technology, when airports redesign major sections of their runway systems (Sparkes, 2010). This dual-use opportunity would allow airports to save time, by closing sections down not only for fixture replacement, but also for runway reconstruction (Sparkes, 2010).

Mr. Mark Williams, P.E. from HNTB Corporation presented "Airport Engineering: The Complete Engineering Package" to the Airport Engineering class on November 11, 2010. The presentation mainly dealt with broad issues across the airport engineering field. However, Mr. Williams explained at length that LED technology was the future of airfield lighting (Williams, 2010). He went on to explain that LED was becoming the most common form of airfield lighting with respect to fixtures that are currently approved by the FAA. Mr. Williams stated that taxiway lighting has been approved for some years, but runway lighting was in the process of being approved by the FAA (Williams, 2010). In addition, airports are not only interested in this technology because of energy savings, but also the fact that LEDs have a long-life span. One problem Mr. Williams discussed was that past LED fixtures were unable to produce enough heat to melt snow on fixtures, during storms; however, newer models have self-regulating heaters that are now installed (Williams, 2010). This allows that LEDs to continue to be cost-effective. Finally, Mr. Williams stated that currently there are no FAA guidelines for LED lighting maintenance (Williams, 2010).

Finally, the design group met with Mr. Donald Elliot on November 13, 2010. Donald Elliot is currently the Interim Airport Manager of COU. He gave the group a tour of the airport facilities, including the Aircraft Operations Area (AOA). The tour included the MALSR located on Runway 02 and ODALS located by Runway 20 as well as all taxiway and runway edge lighting. This opportunity to see the airfield firsthand allowed the group to visualize the lighting systems and the safety issues involved with replacing fixtures (Elliot, 2010).

VII. Projected Impacts

Using all the information described above as well as knowledge of the existing quantity of lights for COU allowed for a cost-analysis to be performed. Through correspondence with Mr. Donald Elliot it was determined to only focus on replacement of the existing taxiway and runway edge lighting at the airport. While additional lighting can be replaced as shown in Table 1, it was reasoned that the majority of cost-savings would come from the taxiway and runway lights. COU has a total of 137 elevated runway lights and 351 elevated taxiway lights spanning two runways and two taxiways. Figure 7 shows the layout of these specific lights using blue dots to represent elevated runway edge lighting and green dots to represent elevated taxiway. Upon various suggestions, ADB Airfield Solutions was decided on for the product to us in a specific cost analysis (2010). Using data collected from their site, the total yearly savings through implementation of LED lighting at COU was calculated. Table 2 shows the variables that were included in the overall calculation for cost savings. These variables include capital, installation, energy, maintenance and replacement costs.

As shown in Table 3 an estimated 2.8 years is needed to fully repay the initial expense for installing and operating LED lights for the elevated taxiway and runway lights. In the analysis it was reasoned that the existing wiring would be sufficient for LED lighting, therefore no costs were included for installation. Additionally, due to the long lifespan of LED lighting no annual maintenance costs were included. The actual lifespan of an LED is difficult to estimate because failure is not binary but involves the luminescence decrease of the overall LED array to levels that are not acceptable.

Figure 7 COU Suggested Lighting Replacement

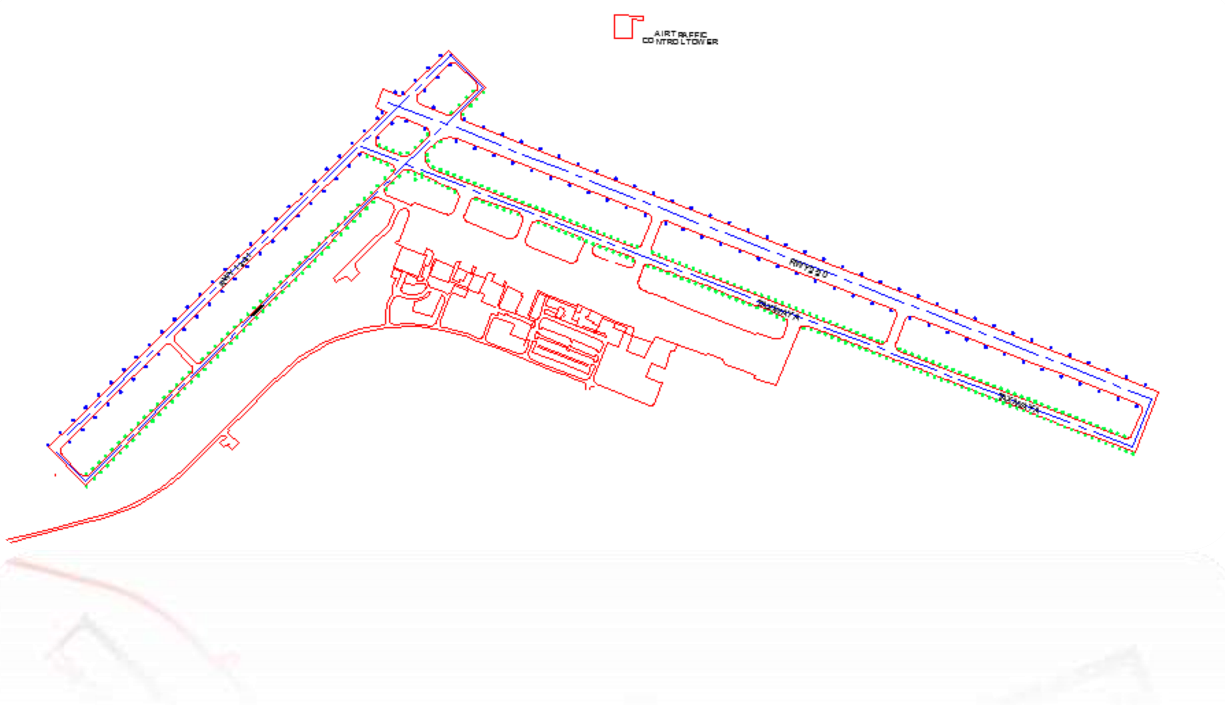

Table 2 Cost Analysis Criteria

System Parameters	LED	Quartz-Incandescent	
Number of fixtures	488	488	
Energy Price (present cost) per kWH ($)	0.04117	0.04117	
Average Operating Time per year in hours	4380	4380	
Number of days/year the temperature might fall below 41°F (5°C)	27.3	27.3	
Maximum SAS LED CCR Load (VA)	32.5	32.5	
Minimum SAS LED CCR Load (VA)	19.5	19.5	
System Factors	**LED**	**Quartz-Incandescent**	**Savings**
Fixture Purchase Cost ($)	$250.00	$50.00	($200.00)
Average CCR Load (VA)	9.99	27	
Energy Cost per Installation per year (calculated)	$1.80	$4.87	$3.07
Average Replacement Lamp Cost	$0.00	$7.75	
Average Replace Lamp Labor and Equipment Cost	$0.00	$26.50	
Average replacements per year	0	2	
Routine Maintenance Cost	$0.00	$68.50	$68.50

Table 3 Estimated Savings for COU

Yearly Savings per Fixture:	$71.57
On Per Fixture Investment of:	$200.00
Total Yearly Savings:	**$34,925**
On Total Investment of:	$97,600
Total Return	36%
LED Return on Investment (ROI) in:	**2.8 years**
Per Fixture ongoing Energy & Labor Cost/Year if Quartz-Incandescent is used instead of LED:	($71.57)
Total Ongoing Energy & Labor Costs/Year if Quartz-Incandescent is used instead of LED:	($34,924.58)

VIII. Conclusions

The conclusions drawn from the case study on COU can be applied to most mid-sized airports with the potential of greater savings when implemented in larger commercial airports. Through analyzing COU, the concept of saving expenses through the use of LED technology was verified. Not only can costs be reduced through energy efficiency but also through annual labor maintenance. As approval through the FAA continues with application of other airfield lighting options for LEDs, the potential to drastically reduce an airport’s lighting expenses will be greatly increase. Additionally, new technology such as LED fixtures that do not require heaters would amplify the savings through electricity usage. It should be noted that while all analysis was performed with only one product option, it is reasonable to believe that similar savings could accrue from alternatives.

Appendix A: List of Complete Contact Information

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Appendix B: Description of the University of Missouri

Figure 8 University of Missouri, Francis Quadrangle

The University of Missouri (Mizzou) located in Columbia, Missouri was founded in 1839. Mizzou was the first public university west of the Mississippi River, and the first public university in the Louisiana Purchase. Moreover, Mizzou is both the state land grant and the research university, and is the flagship University of the University of Missouri System. Mizzou is one of the only six public universities in the nation with medicine, veterinary medicine, and law on one campus. The University of Missouri is a member of the American Association of Universities, which is an association of 63 leading public and private research universities. In addition, Mizzou is classified by the Carnegie Foundation at the highest level for doctorate-granting universities. The Civil and Environmental Engineering Department at Mizzou is made of four groups: Environmental, Geotechnical, Structural, and Transportation. The Transportation Group is made up of five faculty members, and has over twenty graduate students (both Pd.D. and Masters). The group works with other programs associated with transportation research at the University of Missouri, including the Truman School of Public Policy, Agricultural Economics, Statistics, and many others. In addition, Professor Sun, member of the Transportation Group, previously designed aircraft information systems as an employee of Airshow, Inc, now Rockwell/Collins.

Appendix C: Description of Non-University Partners Involved With The Project

For this project, there were no outside partners. However, if further study is conducted, outside collaborators could be contacted.

Appendix E: Evaluation of the Educational Experience Provided By the Project

Sean Collier

By participating in the competition I was able to break out of the standard classroom learning experience and actually talk with industry experts to gain a better understanding of airport operation and the troubles faced by today's airfields.

My team encountered the challenge of finding precise information from Columbia Regional Airport that pertained to the study we were conducting. While we may have preferred this information, we were able to overcome some of the obstacle by performing in-depth research to base some assumptions.

In order to develop a meaningful hypothesis, our team met to discuss current issues many medium sized airports might face. Having a local airport, we knew immediately we would like to perform a case study on COU and apply our findings to other similar airports. Keeping all of this in mind, we created a list of potential options then determined one item from the list that we would like to apply to COU. After confirmation of the need for efficient lighting at the airport, we agreed to perform our report on the implementation of LED lighting in order to reduce electrical costs.

By incorporating participation from industry expects as well as COU employees, we were able to confirm the usefulness of our research. Ultimately, this made the participation appropriate, meaningful, and useful all at the same time. We were able to use our industry contacts to correct assumptions we made as well as answer any questions that were raised during research.

Before researching the typical runway layout for lighting, I did not have any understanding of the placement of lights nor the purpose of most lights. From performing this project, I learned all of this as well as other aspects of daily airfield operations. With this background knowledge, I believe I now have a basic understanding of practical airfield aspects that would help me be successful for entry into the field of airport management.

Mary Hinz

This has been a meaningful experience for me because I don't usually participate in nation-wide competitions like this, so regardless of winning or losing, I feel like I've learned a lot about the FAA and airport engineering in general.

Our biggest challenge was getting all the information from our "industry experts" at Columbia Regional (COU). We still have not overcome this challenge.

We spent several days discussing current issues in the airport industry and discovered energy/money savings was what we were all the most interested in and seemed the most feasible.

Participation by the industry experts was appropriate, meaningful and useful. I really enjoyed our lectures from industry experts, but also the insight provided by the experts at COU was very useful to our project.

I gained a much better understanding for the amount of work/effort goes into all aspects of the airline/field industry.

Wyatt Jenkins

The FAA design competition provided a meaningful experience, because I was able to research a topic in-depth which has a real-life impact at my local airport. This experience is very much real-world.

Several challenges occurred during the competition. First, we had to understand the problem entirely, and define our area of study. Then, we had to acquire light fixture data from COU which caused a large delay. We overcame the data issues by visiting COU and by seeing firsthand what fixtures were installed.

When designing our hypothesis, we looked at many current articles, and communicated with experienced airport engineers. These experiences provided our group with enough evidence to form a hypothesis.

The participation from the industry was crucial, because experts provided detailed evidence of previous lighting issues. In addition, experts are aware of current practice and what is practical in today's engineering environment.

I learned to not only sharpen my engineering skills, but also my social skills. Acquiring data sometimes requires an individual to be very personable and be very persuasive. I believe this project prepares an individual for entry into the workforce, because this experience provides real-life issues (e.g. acquiring data).

Appendix F: Reference List

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