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Implementing Occupancy Sensor Lighting Controls in a University Lab Classroom – a Case Study

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CONTINUING EDUCATION AIA

Background

- Occupancy sensors are lighting control devices that automatically turn lights on when they detect motion, and off when motion is not detected for an allotted time period
- A large number of occupancy sensors exist, and are a simple, affordable method to reduce lighting energy consumption
- One application that underutilizes these sensors is classrooms
- A case study university classroom currently uses an outdated toggle switch system, wasting a large quantity of energy
- This case study examined the use and operating costs of this current lighting control system, a proposed occupancy sensor system, the payback period of the system, conclusions, and recommendations for implementation

Introduction

- An IES paper[1] presents a case study where classrooms with manual controls were monitored for their lighting energy consumption to determine the amount of wasted energy when rooms were unoccupied
- The study revealed that during 20% of daytime and 17% of nighttime, the lights were left on in an unoccupied room
- The paper stated that the installation of occupancy sensors would drastically reduce levels of energy waste
- As a result, occupancy sensors can save hundreds of dollars on annual electricity bills, while preserving fossil fuels and other energy sources

1. Von Nieda B., Manicria D., & Tweed A. (2000). *An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems*. Proceedings of the Illuminating Engineering Society. Paper #43.

Introduction

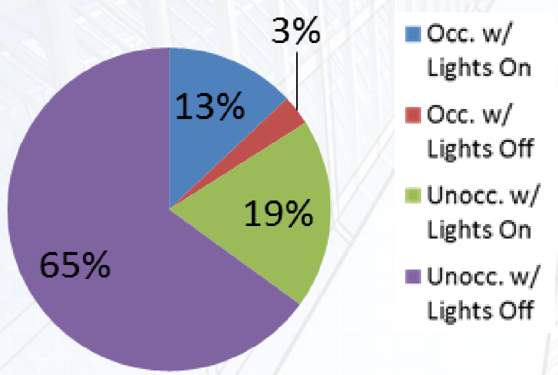

Figure 1
Classroom Lighting Conditions (Von Neida)

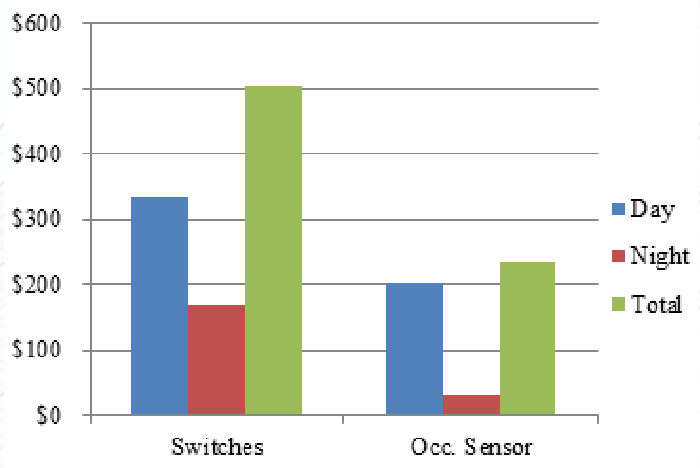

Figure 2
Classroom Lighting Conditions (Von Neida)

1. Von Nieda B., Manicria D., & Tweed A. (2000). *An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems*. Proceedings of the Illuminating Engineering Society. Paper #43.

Introduction

- The case study university hosts a large portion of classes for Construction Management (CM) students
- The students can access lab classroom at any time of the day
- With constant access to the labs, it is probable that an even higher percentage of energy is wasted in these classrooms than those cited by Von Neida
- Student experiences and observations have shown that these labs are often illuminated while unoccupied
- Currently, the lab classrooms utilize manual toggle switches that are assigned to specific lights in each lab
- Due to the developing technology in the lighting controls industry, the current system is not only outdated, but relies too heavily on human control

Objectives

- To present the need for a new lighting control system in the labs
- To identify the maintenance required for the current lighting control system
- To calculate the operation cost of the current lighting system
- To determine an appropriate occupancy sensor system to implement in the labs
- To discover the payback period of the proposed occupancy sensors

Current Design

- In these lab classrooms, the design documents indicate one switch controls a single up-light for 2 rows of light fixtures, while another switch controls two down-lights for the same rows of fixtures
- Therefore, each switch turns on a portion of the lights, and when all switches are turned on, the room is fully illuminated
- Typically, the rooms are fully illuminated during instructional hours

LIGHTING FIXTURE SCHEDULE

CALLOUT	SYMBOL	DESCRIPTION	LAMPS			BALLAST		VOLTS	MANUFACTURER	CATALOG #	MOUNTING
			NO.	WATTS	TYPE	DESCRIPTION	NO.				
G		4" SUSPENDED INDIRECT FIXTURE COMPLETE WITH ONE PIECE EXTRUDED ALUMINUM HOUSING, SPECULAR ALUMINUM REFLECTOR, HPF ELECTRONIC BALLAST, ICLS COMPATIBILITY AND MOUNTING ACCESSORIES AS REQUIRED. LAMP OPERATION: 2-LAMP GENERAL LIGHTING MODE AND 1-LAMP A/V LIGHTING MODE.	3	32	F32/T8	ELECTRONIC	1	277	FINELITE ALERA CORELITE	FORM 10 "IDC" SERIES "A1" SERIES	PENDANT

Figure 1
Lab Classroom Light Fixture

Current Design

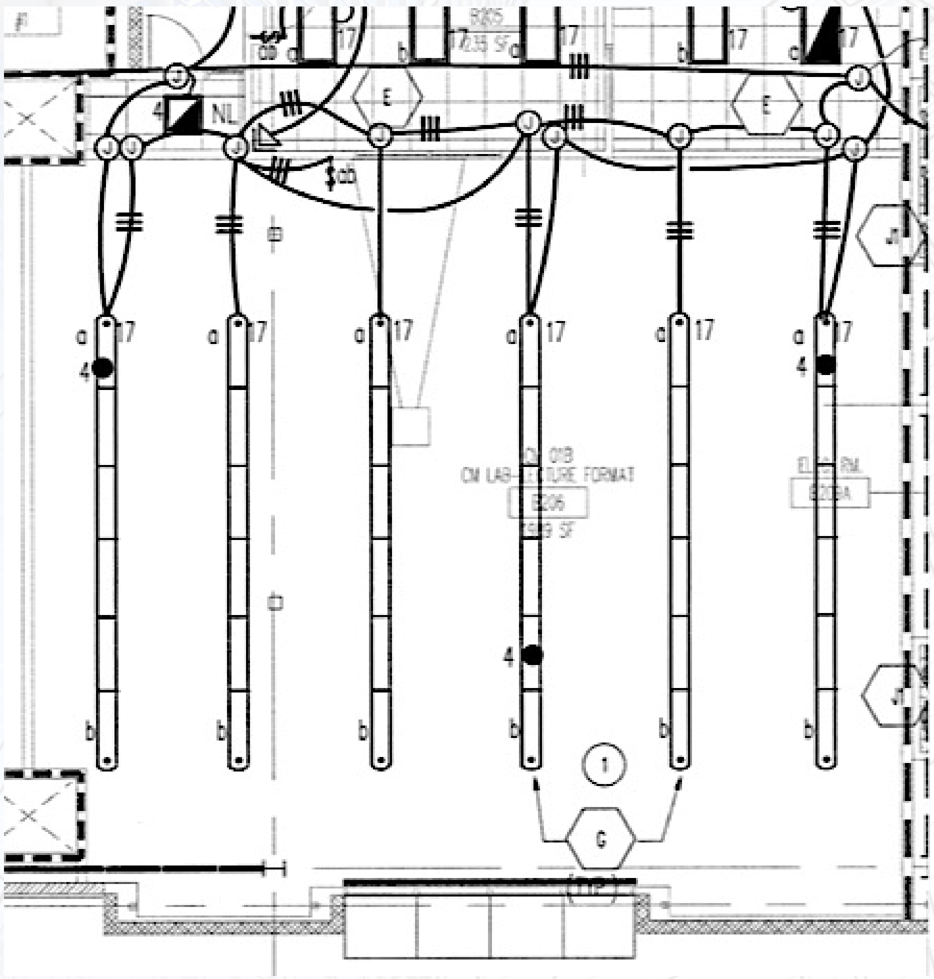

Figure 2
Lighting Plan for a Typical Lab Classroom

Current Design

- The design documents also require automatic lighting control, however, this is achieved thorough relays and a timer, which only control the lights after midnight

LIGHTING MANDATORY MEASURES — **LTG-MM**

PROJECT NAME	DATE
CALIFORNIA POLYTECHNIC STATE UNIVERSITY EDES BLDG. B & C	February 15, 2006

DESCRIPTION			Designer	Enforcement
☑	§ 131(d)1	For every floor, all interior lighting systems shall be equipped with a separate automatic control to shut off the lighting. This automatic control shall meet the requirements of Section 119 and may be an occupancy sensor, automatic time switch, or other divide capable of automatically shutting off the lighting.	Yes	Electrical Contractor

Methodology

- The methodology chosen included fieldwork and qualitative research methods
- A student survey was sent to all CM students to determine how well they managed the current lighting control system
- The survey focused on how often they adjust the lights, if they find empty classrooms fully-illuminated, and other questions to establish a basis of how much energy is being wasted with the current system
- Cost data was gathered and the operating cost calculated for the current system
- This information was used to decide whether occupancy sensors could be beneficial in these classrooms
- An occupancy sensor system was identified, along with its components, features, upfront cost, and payback period

Methodology

- The main issue regarding the existing lighting control system is whether students use it properly to conserve energy
- This system provides the ability to reduce wasted energy
- It can be properly managed by turning lights off before leaving the classroom or only turning on the necessary lights for a workspace, as opposed to illuminating all lights
- However, this current system can also waste a substantial amount of energy, an issue that inspired this study
- Simply by observing these lab classrooms, lights are often turned on at full capacity when there are few, or no, people occupying the room
- To identify whether this observation is mere coincidence or factual, a student survey was conducted, directed to CM students

Survey Questions

- These students typically utilize the classrooms on a daily basis
- Opinions of the students were essential, as they are responsible for managing the use of the current lighting system, and may be unaware of their role in conserving energy
- The survey informed respondents of its focus on CM lab classrooms, and a proposed occupancy sensor system
- Also included was a brief technical summary of the current lighting control system to raise awareness of how the toggle switches can be operated for specific uses, to conserve energy
- Some of the survey questions were applicable to the current toggle-switch system
- The remaining survey questions addressed a new occupancy sensor system and gain opinions on its implementation

Survey Results

- The survey yielded a total of 39 responses
- The overall consensus amongst respondents favored the installation of occupancy sensors
- The responses indicated that a portion of the students adequately maintained the current system, conserving a moderate amount of energy
- One factor to consider is the ages of respondents varied; some may be upperclassmen who are more familiar with the lighting system, and more mindful to operate it efficiently
- Another consideration is that there is no direct correlation between the non-instructional hours of classroom use and the individuals who do not manage the system properly
- Overall, the survey results reveal that the lighting system is not managed properly and wastes energy

Survey Results

- 15% never turned on the lights in any of their lab classrooms
- 56% turn on the lights only once every few weeks
- 28% have never turned the lights off
- 21% have never thought about turning the lights off
- 8% never turn the lights off, even if they are the last person to leave
- 36% turn off the lights sometimes, but not every time, even if they are the last one to leave
- 26% sometimes walk into empty classrooms to find the lights at full capacity
- 46% often walk into an unoccupied, fully-illuminated room
- 21% always walk into an unoccupied, fully-illuminated room

Survey Results

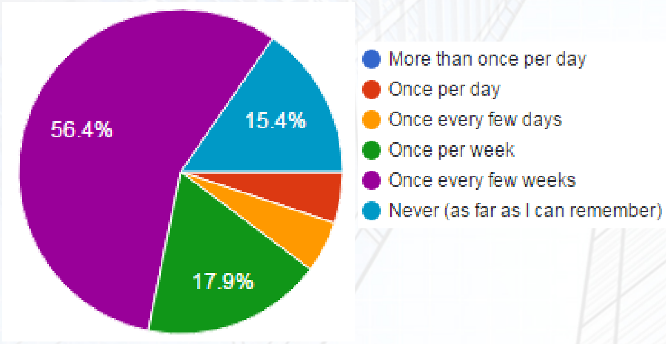

Figure 3
Frequency that Students Turn Lights On

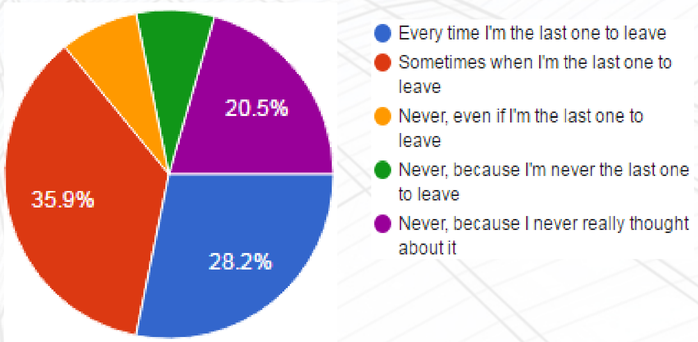

Figure 4
Frequency that Students Turn Lights Off

Survey Results

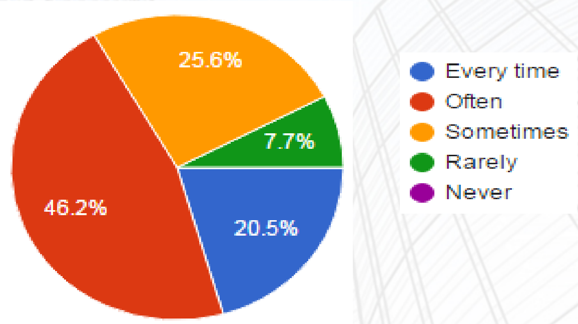

Figure 5
Frequency that Lights are On in Unoccupied Classrooms

Cost Analysis

- The university Facilities department tracks consumption of campus resources, such as electricity, water, and gas
- The goal was to identify the electricity used solely in the lab classrooms, as opposed to campus-wide energy use
- Unfortunately, although the building Secondary Unit Substation has a Supervisory Control and Data Acquisition (SCADA) connection to Facilities, data was not available
- Most of the campus classrooms have implemented a similar toggle-switch system to those in the labs, therefore, the campus consumption rates should correlate with actual use
- However, other classrooms may differ in student-use during instructional hours

Cost Analysis

- According to the Energy and Sustainability Analyst for the Administration and Finance Department, the university's annual blended energy rate is \$0.11/kWh[1]
- Although this does not represent the specific lighting consumption cost of the building, it is assumed that this rate can be applied for the building
- This \$0.11/kWh is a key component in calculating the cost analysis of the current system

1. Veium, E. (2017, March 9). Personal communication

Cost Analysis

- An assumption was made as to how many hours per day lights illuminate each lab classroom
- The current class schedule reveals that some labs are used at least 3 to 4 hours per day for instructional hours, while other lab classrooms host 2 classes per day
- Based on personal experiences and observations, it was assumed that these classrooms' lights are on an additional 12 hours per day, during non-instructional hours
- In this 12-hour span, students utilize their labs to study or work on schoolwork
- Therefore, the lab classroom lights are on approximately 16 to 18 total hours per day

Cost Analysis

- The design drawings indicate each 4-foot light fixture consumes 96 watts using a High Power Factor Electronic Ballast (Figure 1)
- There are thirty, 4-foot light fixtures in each room, and this quantity is multiplied by 96 watts per fixture to produce 2,880 watts consumed per hour
- Assuming $0.11 per kilowatt-hour, this yields an operating cost of approximately $0.32 per hour per classroom, or $1,170.89 per classroom during the school year
- Assuming all lab classrooms consume the same amount, this equals $14,050.71 for all nine lab classrooms

Proposed System

- If an appropriate sensor system is not implemented, or adjusted improperly, it may inadvertently shut off the lights
- Therefore, the sensors must be able to detect the slightest motion, while having a great range of detection
- The Lighting Design Specification requires sensors that use either passive infrared (PIR), ultrasonic, or dual-technology
- Also, they must cover an area of “1,000 sq. ft. when mounted on a 96-inch-high ceiling” and “detect occurrences of 6-inch-minimum movement”
- The selected system has sensors with PIR technology, detecting even the slightest motion in a 1,500 square-foot area
- Accompanying the sensors is a relay module that sends the signal from the sensors to the lights, and wireless controls
- The proposed system cost was estimated to be $532/ classroom

Payback Period of Proposed System

- Assuming a one-year payback period, the total cost of $532 per classroom is divided by the operating cost $0.32/hour/classroom
- This equals roughly 1,680 hours, therefore, the new system needs to conserve 1,680 hours of consumption to pay for itself
- Assuming 44 school weeks, or 308 days, per calendar year, multiplied by the 12 non-instructional hours per day of light consumption, equals 3,696 hours
- Finally, to find the ratio of conservation-hours to consumed-hours, 1,680 hours is divided by 3,696 hours, and equals 0.454
- As a result, the lights must be turned off 45% during the 12 non-instructional hours, or 5.5 hours, to achieve a one-year payback
- Based on the survey results, this 5.5 hours per day seems plausible
- A two-year back requires only 2.75 hours, a very realistic goal

Payback Period of Proposed System

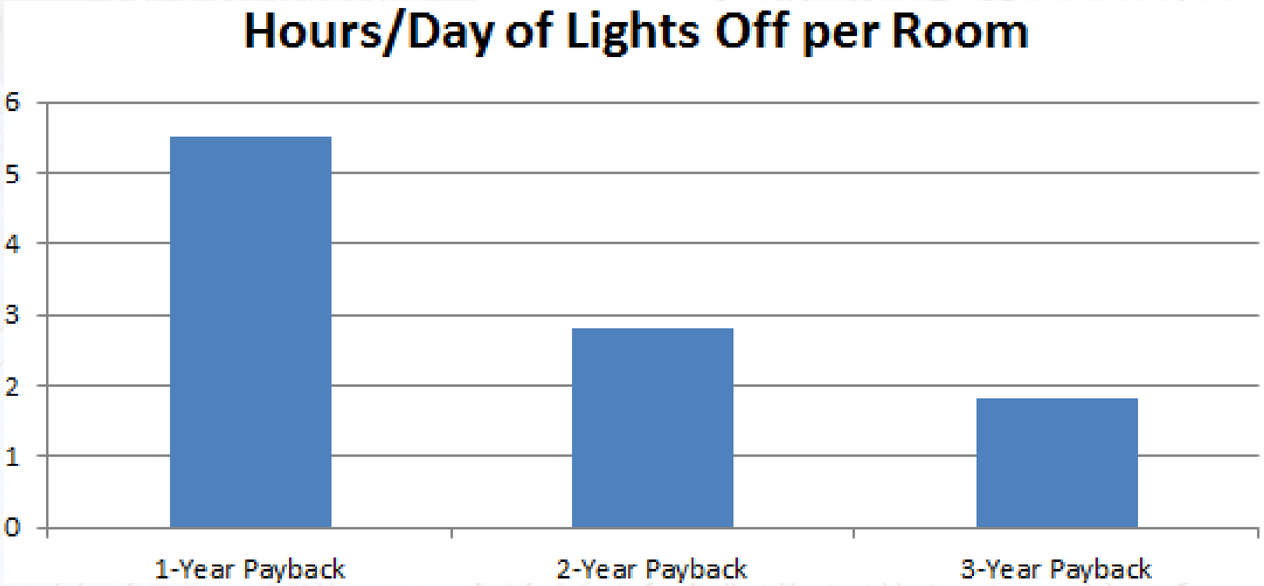

Figure 6
Hours per Day of Lights Off Needed for Payback

Conclusions

- The university CM lab classrooms currently use a manual toggle switch lighting control system
- Various studies, as well as an internal survey, reveal that these systems waste energy when rooms are unoccupied
- A survey showed over 64% of students do not always turn lights off, and over 92% find unoccupied classrooms illuminated
- This wasted energy costs the university over $14,000 in one school year
- This evidence encourages the need to implement a new lighting occupancy lighting control system
- A proposed PIR system appropriately addresses the size and motion-detection specifications required in the lab classrooms, while remaining very affordable
- The proposed occupancy sensors conserve enough energy to reasonably payback their initial cost within one year

Future Research

- Gathering accurate data of lighting consumption in classrooms would prevent the need to make assumptions, and allow researchers to determine actual costs, as well as the precise payback period of a proposed new system to implement
- The consumption data can be obtained with the use of lighting loggers, which measure the amount of lighting consumption
- Occupancy sensors are progressing in various applications, and their implementation in classrooms has steadily increased
- With more efficient performance of occupancy sensors and the recent development of strict energy codes, they are becoming more appropriate to include in either new or existing classrooms
- Future researchers should make sure these new sensors comply with state energy codes, such as CA Title 24, and should specify exact locations for installation