An examination of lighting system energy and cost savings for cafeterias at the workplace

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Abstract

The purpose of this study was to examine lighting system energy and cost savings at an existing U.S. Government facility's cafeteria. The objectives of the study included (1) investigating and documenting existing lighting systems and measuring lighting levels, (2) comparing findings to the industry lighting standards, and (3) making lighting recommendation for energy and cost savings. Lighting examinations and field measurements were conducted at an existing Mid-western U.S. Government facility's cafeteria built in 1976 and currently in operation. Four spaces: the dining room, checkout line, buffet and kitchen were included for this study. The light levels in the two measured areas which had both *electric light and daylight* contributions, the checkout line and dining room, exceeded the industry recommendations for lighting levels. The other two areas, the buffet and kitchen, were illuminated by *electric light only* and exhibited no daylight contributions. The average light levels in the buffet area, one of the two measured areas which had *electric light only,* exceeded the industry recommendations for lighting levels. For energy and cost saving, de-lamping all six-lamp luminaires down to three lamps in the dining room, replacing lamps in the checkout line and installing occupancy sensors for all four areas were recommended. The cost savings were calculated. If existing lighting can be updated in an energy and cost saving manner, cafeteria lighting might be made appropriate through renovation, thus extending the life of this and other existing workplace cafeterias.
Keywords: lighting, energy, cost, cafeteria, workplace.

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1 Introduction

Traditionally a cafeteria was generally arranged with one large kitchen positioned away from the main dining area, food was presented in straight serving lines and displayed in steam-table pans; and seating consisted of stackable chairs placed around long tables [1, 2]. In the dining area, lighting was most often composed of linear fluorescent lighting configured in long rows that reflected light up to the ceiling and back down to the floor [3]. This type of lighting could be very bright and contributed to eye strain. Other than the large traditional cafeteria, some workplaces have begun to offer their employees a range of dining options, as administrators understand that having healthy employees is critical to work productivity [4]. A good cafeteria has been found to improve employee morale and reduce employee turnover [5]. These benefits may be due to the cafeteria's standard provision of a common meeting space where employees can break from their desk work and change their environment [4]. Cafeterias have also been known to contribute to a productive working environment (Humphrey [5]). Without the need to leave the facility for food, employees may not take as long of a lunch break [6, 7]. Quite often, employers provide cafeterias as part of the benefits program for their employees and all parties may reap for such time-saving benefits [6, 8].

The benefits companies have seen from providing employees with cafeterias may have also stemmed from the "restorative properties" associated with these environments. According to Berto [9], an individual may develop mental fatigue after intensive or sustained work activity, causing that individual to have a harder time concentrating and avoiding distractions. Individuals can rebuild their attention capacity by being exposed to restorative environments that contain soothing natural elements such as a landscape of trees or mountains. Rashid and Zimring [10] reviewed multiple studies which showed that stress may lead to negative outcomes in the physiological, psychological, cognitive, behavioral, psychosocial, and social realms of individuals' lives. Environmental elements such as lighting, noise, temperature, air quality, color, and overall design have been shown to influence the outcomes of the aforementioned characteristics and may positively or negatively affect individuals to different degrees. Examples of how individuals have been negatively affected by their surroundings may include headaches, seasonal affective disorder, eyestrain, reduced productivity levels, and poor mental performance among others.

In terms of cafeterias or other foodservice spaces, many employees may venture from their offices to these areas for breaks, and especially during lunchtime. Han [11] proposed that people tended to prefer natural elements for restorative environments. He suggested that these environments could evoke positive behaviors, improve cognitive functioning, benefit restoration, and aid stress reduction. Utilizing these findings in cafeterias and other workplace dining facilities could greatly add to the benefits such spaces already offer employees. Research has shown that even artificial representations of natural environments, such as photographs or videos of nature, contribute to the restoration process and may also reduce work-induced stress and "burnout syndrome" [12]. By incorporating decorative and aesthetic objects into cafeterias employers may keep their employees closer to the workplace.

Though cafeterias may bring companies many benefits, employers have begun to cut them out of their budgets due to financial challenges that have arisen during the last few decades. Alongside business cafeterias, school cafeterias have suffered losses as their patrons find the facilities' setups to be outdated, old fashioned, and unappealing [1]. Traditional cafeterias regularly contain harsh fluorescent lighting that produced bothersome sounds and irregular light output [13]. Perlik [14] noted that these issues were causing these facilities to lose their patrons to other foodservice options. Other problems found in traditional cafeteria design were the use of stark, impersonal materials, the long lines of patrons that formed due to the service line arrangement, and the low ceilings. Bauroth [15] mentioned that dining facilities often wound up in cut-off spaces in buildings as poorly designed afterthoughts, which may yet be another reason they began to fail. As fast food options have become readily available, cafeterias now have higher levels of competition giving employees more reasons to leave their workplaces in search of other foodservice options [6, 16]. White [8] found a negative correlation between the number of employees' options to eat away from their workplace and their productivity levels. Due to the aforementioned problems, many companies have shifted their dining options away from the traditional cafeteria setup to that of a more restaurant-style atmosphere. Other profound changes in the redesign of outdated cafeterias were likely to have arisen due to concerns for energy conservation and sustainable design. However, many older styled cafeterias are still in operation in the U.S. and renovation may increase their viability [17].

Lighting is often improperly selected and underutilized in foodservice facilities though it has been found to greatly influence dining and kitchen quality [18]. As previously noted, lighting has been among the traditional cafeteria's problematic design issues. Therefore it is important to discuss the impact lighting may have on various foodservice facilities and the supporting background. Cafeteria design as a whole has been widely addressed by design professionals, though very little of the research has appeared in scholarly articles. The majority of literature available concerning traditional cafeteria design, renovations, and updates is typically limited to articles examining the general aspects of completed projects. Many of these projects utilize new concepts in foodservice design but provide little to no background information or references to previous research. A proper lighting system is important to the cafeteria environment and can help to save energy and costs [19, 20].

This study proposed updates to the existing illumination of one operating cafeteria and reported anticipated energy and cost savings. If existing lighting could be updated in an energy and cost saving manner, then the cafeteria's lighting might be made appropriate through renovation, thus extending the life of this and other existing cafeterias. The purpose of this study was to examine lighting systems at an existing U.S. Government facility by conducing field measurements of illumination and comparing them to the Illuminating Engineering Society of North America (IES) lighting standards to inform specific lighting recommendations for energy and cost savings. The objectives of the study included (1) investigating and documenting existing lighting systems and measuring lighting levels, (2) comparing findings to the industry lighting standards, and (3) making lighting recommendation for energy and cost savings.

2 Cafeteria facility

Since by today's standards there are many problems with traditional cafeteria designs, changes in building codes and implementation of the Americans with Disabilities Act as well as other new lighting, safety, and ventilation standards may also justify renovation [8, 21]. Other changes to traditional U.S. cafeterias have been promoted and incorporated as employers have begun to fully understand the benefits of having an attractive dining facility. Renovation may improve employee morale, productivity, and retention in the workplace [4]. Boss [1] noted that updates were needed as potential patrons had developed higher expectations for their dining experiences and wanted better quality food, a more pleasant atmosphere, and improved traffic flow through service lines.

Many of the radical changes implemented in the relatively recent redesign of cafeterias in the U.S. have focused on materials and layout. Bauroth [15] noted that numerous businesses updated their traditional cafeterias into relaxing spaces for employees. Restaurant-style lighting such as pendants or track lighting was installed as opposed to harsh, institutional fluorescent luminaires. In addition, the hot and cold line layout established in traditional cafeterias began to be replaced with individual meal stations that prepared food "out front" and creatively displayed food products to entice customers [8, 14]. In schools, hospitals, and businesses alike, foodservice facilities were created utilizing individual meal stations that offered variations in food choices, visual themes, seating, and finish materials [2, 16, 21]. In some businesses, various means of meal delivery were instituted as ways to support employees who chose to work through their lunch break [6].

The recent changes made to cafeteria design have begun to accommodate customers' desires. Atmospheres have become enjoyable, traffic circulation has improved, and the overall appeal of foodservice facilities has increased [14]. According to White [8], with these changes came other signs of progress in newly renovated foodservice facilities. Employers began to see employees opt to "eat in" at the company cafeteria as opposed to "going out". Holaday [22] suggested that administering surveys to gather feedback from students was one way school's foodservice facilities could begin their restoration process. During some of the survey sessions, designers found that participants enjoyed the "restaurant-style" environment with various seating choices. Also popular was the new development of individual food stations. Patrons enjoyed the various themes and selections in food choices in addition to updated and aesthetically pleasing environments [1, 2, 23]. Feedback from surveys in other foodservice renovations conveyed that patrons enjoyed having shorter lines with less traffic and they believed facilities were more efficient when everything they needed was within easy reach [7, 8]. Other new, patron-supported foodservice features include a variety of seating options, the installation of LCD screens, and free wireless internet service [2, 23].

These changes in cafeteria design may offer employees a relaxing respite from their work that includes an enjoyable atmosphere, a variety of high-quality food, and attentive service [4].

Energy conservation and sustainable design were other issues considered in the redesign of outdated foodservice facilities. As energy conservation became important, the use of skylights and energy efficient lighting was implemented [2, 3, 22]. By harvesting daylight and installing reactive lighting accessories such as dimming controls, natural lighting was used to the best extent possible [16]. Other lighting devices used to detect occupancy and decrease energy usage were commonly installed [22, 24–26]. Penny [27] noted that when energy conservation was monitored, it could affect occupant use and could influence behavior. Other opportunities in the redesign of foodservice facilities were in the area of sustainable design. The U.S. Environmental Protection Agency's (EPA) cafeteria in Washington DC became the first completely sustainable cafeteria in the U.S. [28]. Its operations were modified to incorporate recyclable and biodegradable dishware, locally grown produce, and environmentally friendly cleaning products [22, 23, 29].

Lighting design and selection are significant in the creation of an environment and may affect individuals' visual perceptions of that environment [30]. Lighting that is properly designed and installed can affect food presentation, ensuring that it looks natural and appetizing to patrons. Food may appear best when light is focused on table tops, food displays, and work areas as compared to focusing on walls, ceilings, or floors [3, 18]. Food displays and work areas can be illuminated via solutions such as directional drop pendants or compact fluorescent lighting and these lighting solutions can work together to increase decoration and interest as some areas become highlighted [14]. While it is important that preparation areas are well illuminated to decrease the chances of accidents or other mishaps, it is essential that the different lighted areas appear distinct from one another which enhances the effect of the lighting design as a whole [13, 31]. Suitable lighting within a foodservice facility can create ambiance, make food products look appealing, and draw-in customers [31]. Appropriate lighting may also enhance the appearance of people within the vicinity and increase patrons' level of comfort [13, 18]. Actions may be taken to ensure that the proper electric lighting levels are maintained throughout the day by using lighting controls such as dimmers that adjust to the natural light that filters into the environment [3]. Lighting selections can also affect foodservice facilities' operating expenses as some lamp options such as light emitting diodes (LEDs) can be used to conserve energy and also minimize maintenance [25]. While some documented negative perceptions of fluorescent lighting were perceived with the traditional design of cafeterias (i.e. harsh glare, buzzing or humming noises, and inconsistent light output), more recent findings show that appropriate lighting may have the opposite (positive) effect for a foodservice facility. Ensuring that proper lighting is utilized may be a contributing factor to the successful renovation of a traditional cafeteria.

3 Methods

For this in-situ case study, lighting examinations and field measurements were conducted at a large, existing Mid-western U.S. Government facility's cafeteria which has been continuously operational since 1976. The researchers gathered data inside the cafeteria building, which was selected for study from numerous buildings in the governmental complex by the owner's representative. The following four spaces in the cafeteria building were examined: dining room, buffet, checkout line, and kitchen.

The researchers counted luminaires (industry term for light fixtures) and lamps (industry term for light bulbs) in each area, manually sketched luminaire locations, produced photo documentation of existing luminaires, determined the number of existing luminaries and lamps per room, recorded lighting control types (i.e. switches, dimmers, daylight sensors/daylight harvesting, occupancy sensors, etc.) and luminaires' physical locations, and identified existing luminaire and lamp types.

In areas with windows, light levels were measured in two sessions both with and without daylight contributions. Following industry-recommended procedures [32, 33], researchers utilized an Amprobe LM 120 digital light meter with a remote photocell paddle to measure horizontal lighting levels at standard workplanes: heights 2'–6" above finished floor (AFF). Measured light levels were compared to the IES standards that the researchers deemed applicable and discrepancies were noted. IES standards were selected for this study because IES is considered to be the foremost lighting authority in North America producing such resources as lighting design guidelines, a comprehensive lighting handbook, technical lighting publications and guidelines for lighting measurement [34]. It is the mission of the IES "to improve the lighted environment by bringing together those with lighting knowledge and by translating that knowledge into actions that benefit the public" [35]. The researchers also generated new lighting plans to document existing conditions, entered data into newly developed spreadsheet instruments, created "control sheets" to visually document each luminaire, calculated watts/square foot, and calculated anticipated energy reduction and cost reductions based on retrofit proposal.

4 Findings

4.1 Existing lighting systems

A summary of the existing lighting systems in each of the four examined areas is provided in Table 1. The dining room lighting represented the greatest energy usage of the four areas with a total consumed wattage of 24,576. Existing lighting in the buffet area used the least amount of energy with 780 watts consumed. Incandescent lamps were used only in the checkout line; all other areas used T8 fluorescent lamps. The checkout line also contained the fewest number of luminaires (12) and the fewest number of lamps (12). Lighting in all four areas was manually controlled only by toggle switches. Luminaires in the buffet and checkout line areas were suspended while an integrated coffer lighting system was used in the dining room; luminaires in the kitchen were recessed.

Table 1: Existing lighting.

Dining room						
Number of luminaires	Number of lamps per luminaire	Total number of lamps	Number of watts per lamp	Total lamp wattage	Fixture mount	Lamp type
128	6	768	32	24,576	Recessed*	T8
Buffet						
Number of luminaires	Number of lamps per luminaire	Total number of lamps	Number of watts per lamp	Total lamp wattage	Fixture mount	Lamp type
39	1	39	20	780	Suspended	T8
Checkout line						
Number of luminaires	Number of lamps per luminaire	Total number of lamps	Number of watts per lamp	Total lamp wattage	Fixture mount	Lamp type
12	1	12	250	3,000	Suspended	BR30
Kitchen						
Number of luminaires	Number of lamps per luminaire	Total number of lamps	Number of watts per lamp	Total lamp wattage	Fixture mount	Lamp type
53	2	106	32	3,392	Recessed	T8

*in Integrated Coffer System.

4.2 Existing vs. recommended lighting levels

In the years after the building was originally constructed, the industry recommendations for light level have changed for some visual tasks. For example, the level of maintained illuminance for horizontal targets in the dining area of a food service facility as recommended by the IES increased from 100 lx (9.3 fc) in 2000 to 150 lx (13.9 fc) in 2011. The IES recommended levels for food service cashier areas decreased from 500 lx (46.45 fc) in 2000 to 200 lx (18.58 fc) in 2011. Buffet area illuminance recommendations were modified to include a lower range from 500 lx (46.45) to 200-500 lux (18.58 fc - 46.45 fc). No change in maintained illuminance for the kitchen area of a food service facility was recommended by the IES from 2000 to 2011. Rather, the recommended level remained constant at 500 lx (46.45 fc) [32, 33].

Data collected at the cafeteria in the current study and anecdotal information received from on-site building managers revealed that lighting accounted for 7.8% of the cafeteria's overall energy consumption. Researchers gathered field evidence to support the design of a lighting retrofit. This report presents four examined areas related to food service and dining for which the researchers had collected usable lighting data: the dining room, buffet, checkout line, and kitchen. In the areas where both *electric light and daylight* contributions were found, the light level measured was 82.8 fc (891.25 lx) in the dining room and 89.05 fc (958.53 lx) in the checkout line. The light levels in the two measured areas which had both *electric light and daylight* contributions, the dining room and checkout line, exceeded the industry recommendations for lighting levels. The other two areas, the buffet and the kitchen, were illuminated by *electric light only* and exhibited no daylight contributions. The *electric light only* light levels measured in the food service areas were 56.08 fc (603.64 lx) in the buffet and 33.12 fc (356.5 lx) in the kitchen. The average light levels in the buffet area, one of the two measured areas which had *electric light only*, exceeded the industry recommendations for lighting levels.

4.3 Cost and energy savings

The light levels measured in three areas of the cafeteria exceeded industry recommendations. For cost and energy savings, the researchers recommended both de-lamping all six- lamps luminaires in the dining room down to three-lamps and replacing incandescent lamps used in the checkout line with LEDs. Additionally, installing occupancy sensors to control electric lighting in the dining room, buffet, checkout line and kitchen areas was recommended.

4.3.1 Delamping

Cost savings and energy savings were anticipated by delamping the existing 6-lamp 32 Watt T8 fluorescent luminaires to 3-lamp luminaires in the dining room are presented. The annual cost savings anticipated by delamping the dining room was 1,155.07 U.S. Dollars. It was calculated by the following equation (1):

$$\text{\$.047/KwH x 3 lamps x 32 watts/lamp x 128 luminaires in the dining room x 40 hours/week x 50 weeks/year*} \tag{1}$$

(*50 weeks were utilized to account for 2 weeks of holidays.)

24,576,000 Watts of annual energy savings was anticipated by delamping 6-lamp 32 Watt T8 Fluorescent luminaires down to 3-lamp luminaires in the dining room. The following equation (2) was employed for anticipated energy saving:

$$\text{3 lamps x 32 watts/lamp x 128 fixtures in the dining room x 40 hours/week x 50 weeks/year} \tag{2}$$

4.3.2 Replacing lamp and luminaire

Cost savings and energy savings were anticipated by replacing single-lamp 250 Watt BR30 Incandescent luminaires with single-lamp 36 Watt BR40 LED luminaires in the checkout line. 241.39 U.S. Dollars of annual cost saving was calculated based on the following equation (3):

$$\$.047/\text{KwH} \times 1 \text{ lamp} \times 214 \text{ watts/lamp} \times 12 \text{ of luminaires in the checkout line application} \times 40 \text{ hours/week} \times 50 \text{ weeks/year} \quad (3)$$

5,136,000 Watts of energy savings was annually anticipated by replacing single-lamp 250 Watt BR30 Incandescent luminaires with single-lamp 36W BR40 LED luminaires in the checkout line. The following equation (4) was used for annual energy saving calculation:

$$1 \text{ lamp} \times 214 \text{ watts/lamp} \times 12 \text{ luminaires in the checkout line application} \times 40 \text{ hours/week} \times 50 \text{ weeks/year} \quad (4)$$

4.3.3 Installing occupancy sensors

For all four areas, the researchers recommended installing occupancy sensors. Four occupancy sensors were recommended for the dining room, a relatively larger space, while two sensors were recommend for the buffet area. Only one occupancy sensor per area was recommended for both the kitchen and the checkout line. Initial cost to purchase and install occupancy sensors will be 108 U.S. Dollars per occupancy sensor based on the following equation (5):

$$\$75.00 \text{ per occupancy sensor/dining room} + 0.33 \text{ hours of electrician's time} \times \$100.00 \text{ cost rate/ hour*} \quad (5)$$

(*Cost rate/hour includes electrician hourly pay rate, labor burden, overhead, etc.)

Anticipated costs to install occupancy sensors in all four areas are illustrated in Table 2. The table also includes anticipated cost and energy savings for installing occupancy sensors. For cost and energy savings calculation, the two following equations (6), (7) were employed respectively:

$$\$.047/\text{KwH} \times \text{number of sensors per area} \times 10 \text{ hours/week*} \times 50 \text{ weeks/yr} \times \text{total lighting watts/area} \quad (6)$$

$$\text{Number of sensors per area} \times 10 \text{ hours/week*} \times 50 \text{ weeks/yr} \times \text{average total lighting watts/area} \quad (7)$$

(*It is hypothesized that occupants are absent from the area up to 10 hours/week but currently leave their lights ON during those hours.)

It was found that payback time for installing occupancy sensors would be less than one year for the dining room and less than two years for the checkout line and kitchen. For the buffet area, it will take around six years for complete payback. The total energy saving for installing the total of eight sensors would be 53,128,000 Watts.

Table 2: Anticipated cost and energy saving for installing occupancy sensors.

Area	Number of sensors	Initial cost for sensors*	Annual cost savings	Annual energy savings	Payback time
Dining Room	4	$432.00	$2,310.14	49,152,000 Watts	1 Year
Buffet	2	$216.00	$36.66	780,000 Watts	6 Years
Checkout Line	1	$108.00	$70.50	1,500,000 Watts	2 Years
Kitchen	1	$108.00	$79.71	1,696,000 Watts	2 Years

*Estimated materials and installation costs

Note: The cost and energy savings of the dining room and checkout line were calculated before delamping and replacing lamps.

5 Discussion and conclusions

This research constitutes an in-situ case study which gathered empirical lighting data at an existing workplace cafeteria and made recommendations for lighting renovations. The renovations are anticipated to provide energy and cost savings while increasing the cafeteria facility's useful life and relevance. This work has practical implications for the many existing cafeterias in workplaces across the U.S. cafeterias have been shown to provide workers with a welcome respite from their desk work and increase worker productivity as their lunch break at a cafeteria requires virtually no travel time. Lighting is an important component in any food-service facility. Over the years, industry lighting standards, lighting system technologies and patrons' overall expectations for dining have changed. Cafeterias may be made more viable in the workplace through lighting renovations with resulting triple bottom line benefits for people (worker-patrons), prosperity (saving money on lighting systems and on off-site dining) and the planet (saving energy increases sustainability).

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