Considering the Illumination of a University Library Browsing Room: A Case Study of Existing Conditions and Retrofit Recommendations

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Abstract

Interior lighting in university libraries should provide appropriate lighting levels and styles for diverse library users to perform associated visual tasks. Beyond reading and writing, new modes of research and socialization need to be considered for the lighting design of university libraries. The purpose of this study was to examine the illumination of a university library browsing room. The specific aim of this study was to assess the existing conditions by comparing to industry light level standards for retrofits recommendations. Observational Field study was conducted, and field measurement of illumination was taken. The current light levels were compared to the industry light level recommendations by the Illuminating Engineering Society. The findings showed that the current light levels didn't comply with industry lighting recommendations. Lighting retrofit with light-emitting diode (LED) lighting fixture to provide higher lumens per watt was recommended for the university library browsing room. The proposed LED wall sconce with a scroll design and a custom finish is anticipated to be perceived as compatible with the browsing room's historic interior design. This field study adds value by providing ways to promote the library patrons' various visual task performance. Further study can be conducted considering daylighting, seasonal and weather variations at multiple sites.

Keywords: University, lighting, LED, case study

1. Introduction

Emerging library designs, as well as library renovations, increasingly call for the specification of lighting systems that reduce electric energy consumption [1]. Whether this is achieved through fenestrations to increase daylighting for reading or event spaces, or through the retrofit of existing lighting fixtures with LED lamps, the overall lighting design should emphasize visual comfort and promote the health, safety, and wellbeing of users [1]. Reading is ultimately the most critical task in libraries, but as the scope of tasks and media used in University libraries increases, various considerations for lighting emerge [2]. As such, the need for proper lighting in libraries is continuously growing, but the research related to the library lighting has not been much conducted. The purpose of this study was to examine the illumination of a university library browsing room. The specific aim of this study was to assess the existing conditions by comparing to industry light level standards for retrofits recommendations.

Definitions

"Browsing Rooms" are reported by [3] to be

> "alluring spaces in the…university library… (which) are vestiges of the
> 1920s and 1930s, developed in an era when academic libraries vigorously promoted recreational reading interests of students. As repositories of works chosen from the main collection for their ability to uplift, relax, and stimulate the student reader..." (p. 1).

The following quantitative terms are used in this study:

> Efficacy: "…ratio of Lumens per Watt" ([4], p13.2).
> Illuminance: "…incident luminous flux density on a differential
> element of a surface…expressed in lumens per unit area…" ([4], p. 5.10)
> Lux: "lumens/square meter, lx" ([4], p. 5.10)
> Source: "a source of light. It can refer variously to an electric lamp, am LED, and entire luminaire with lamp am optical control, or fenestration for daylighting." ([4], p. 5.2)

1.1 Libraries' Evolving Purposes and Visual Tasks

Over the last few years, the purpose of University libraries has been shifting to accommodate new modes of research, work, and socialization. In response, the lighting design of these spaces are becoming more complex [5, 6]. While reading, writing and researching are still taking place in libraries, the range of visual media is expanding. Now, electronic media are supplementing or even replacing the necessity of print media for

academic research [7]. Computer tasks may also provide flexibility in where users read and write. Reading areas, maybe formal as well as casual spaces [4].

1.2 Visual Ages of End-Users and Lighting Requirements

Reading areas and other activities (visual tasks) require minimum light levels and specific recommendations are made by the Illuminating Engineering Society (IES) for end-users of all “visual ages” [4]. Maximum wattage of electric lighting is often limited by energy standards [2]. Because of energy standards and the need to facilitate more efficient lighting designs, some libraries are now underlit and some have uneven illumination [8]. Ironically, “bare” lighting fixtures (without lamp shielding) may be especially problematic for some patrons, especially older adults, due to the resulting glare [9]. Although experts agree ambient lighting should remain uniform throughout a library, other lighting techniques, such as task and indirect lighting, can be used to emphasize different areas and aid end-users in accomplishing visual tasks [1].

University libraries cater to traditional undergraduate students (approximately 18-22 years old). University libraries should also recognize that many of their end-users are not traditional students; therefore, libraries must support the needs of the following groups as well: “non-traditional” or returning undergraduate students, graduate students, staff, faculty members and community members. It is anticipated that many of these library end-users will be between 26 and 65 years old; or over 65 years old. In consideration of the physiological needs of older adults (and those persons of any age with vision problems), who require more light than younger individuals to see clearly, the IES recommends the various respective illuminances for “visual age” groups: 269.1 lux, for persons whose visual ages are below 25; and 1076.4 lux for visual ages above 65 for all horizontal reading tasks [4]. Similarly, for vertical reading tasks, the IES recommends 107.6 lux for visual ages below 25; and 430.6 lux for visual ages above 65 for all reading areas except stack areas [4]. For stack reading areas, the IES recommends 53.8 lux for visual ages below 25; and 215.3 lux for visual ages above 65 [4]. For book stack tasks in general, the IES recommends 107.6 lux for visual ages below 25; and 430.6 lux for visual ages above 65, but also advises that automatic sensors be utilized in these areas to reduce lux by half after periods of inactivity [4].

Libraries are also expanding their services to best fit the needs of their end-users and common areas may now include cafes, collaborative lounges, and event spaces [2]. In café areas, the IES recommends 53.8 lux for visual ages below 25; and 215.3 lux for visual ages above 65 for general tasks [4]. For end-users browsing on personal electronic devices in these areas, the IES recommends 80.7 lux for visual ages below 25; and 322.9 lux for visual ages above 65 [4]. Similarly, in lounge or club rooms, the IES recommends 21.5 lux for visual ages under 25’ and 86.1 lux for visual ages above 65 for general tasks [4].

1.3 Lighting Techniques in Libraries

Indirect lighting (uplighting) techniques are recommended to create consistent illumination in a library, but designers should be wary of over-illumination and correspondingly high energy consumption [1]. Indirect lighting is defined by [8] as “the intentional application of light that is to be controlled by reflecting it off surfaces whose color and texture are also controlled” (p. 335). Indirect lighting techniques are favored for visual comfort since the lamps are hidden from view and light is diffused by bouncing off surrounding surfaces, and indirect lighting produces less glare than direct lighting [2, 8]. The reflection of indirect lighting systems off of multiple room surfaces also reduces shadowing and contrasts, which is especially important for the aging eye [9].

Indirect lighting is optimal for wayfinding when used atop stacks to produce a pleasant and non-directional glow [2]. Indirect fixtures can be mounted directly to the book stack if ceilings are low enough to reflect light from the lamp, but in ceilings over 10’-0”, fixtures should be suspended [2]. In suspended systems, fixtures can run parallel or perpendicular to stacks. Indirect lighting techniques are favored, especially in University libraries, due to its appropriateness for both paper and electronic tasks [2].

The technique of *task lighting*, in contrast, should be aimed in a specific direction to spread light evenly across a task (Malman, 2001). Adjustable task lights are preferred so the angles of the light can be adjusted based on end-user preference [2]. In general, 161.5 lux of task lighting are required by support staff for general paper-based working and book sorting [4]. For reading, illumination level recommendations vary depending on the visual medium [2]. For visual ages of 25 and younger, reading 12-point font on print media 107.6 lux is recommended, while for 6-point font, 161.5 lux is recommended [4]. For those with visual ages 65 and older, 12-point font, 430.6 lux is recommended, and for 6-point font 1,076.4 lux is recommended [4]. For electronic media, such as computer screens, IES recommends 161.5 lux for visual ages 25 and younger, and 645.8 lux for visual ages 65 and older [4].

1.4 Light Emitting Diodes (LEDs)

Today, light emitting diodes (LED) are often recommended for commercial building spaces, such as University libraries. LEDs are described by LEDs Magazine [10] as “semiconductor device(s) that emit light when an electric current is passed through it” (pg. 1). Because LEDs emit light from a semiconductor comprised of positively and negatively charged solid matter, they are also referred to as “solid-state lighting” [11]. Other electric light sources, including compact fluorescent, metal halide and incandescent are also found in existing libraries. All of these sources have a lower lumens per watt than LEDs [12, 4].

LEDs area favored because of their energy-efficient technologies and optimal lumen output [13]. Although LEDs also have attractive attributes, such as longer lifetimes and environmental advantages, other lamp types are still preferred by some because of the higher initial cost of LEDs. However, in a study by [14],

replacing fluorescent lamps with lower wattage LEDs reduced costs. Because of LEDs' ability to project light directionally, LEDs are more optimal when used for task lighting, uplighting, or downlighting, as the full intensity of light will be cast on the desired surface [13].

Most commonly, LEDs utilize red, green, and blue light diodes, combining to produce a white light [13]. Although classified as white LEDs, the color of these lamps can be inconsistent in color temperature and create different perceptions [15]. LEDs can produce light whose color temperature (visual perception of warmth or coolness) are reminiscent of other sources, such as natural daylighting. Natural daylighting is generally preferred by most due to its visual comfort and natural daylight is still present in many libraries today [6]. Unfortunately, the Ultraviolet radiation associated with natural daylighting can be harmful to printed materials, such as books [16].

1.5 Existing Conditions

The electric lighting system in the University library building, which houses the Browsing Room in the current study, had originally been installed in 1953. The Browsing Rooms had been re-lamped in a 1999 remodel [17]. Prior to the current study, the researchers were advised that the library had collected anecdotal evidence of discontent with the Browsing Room. Complaints had been received that the Browsing Room appeared dim and that many felt that the existing indirect "scoop" wall sconces' aesthetic was too modern for the library's classic architecture and furnishings. The researchers had surveyed library end-users (students, faculty, staff and community members) and gathered perceptions about the library's interior lighting and sustainability [17].

2. Research Methodology

2.1 Observational Field Study of Existing Conditions (Case study)

The current research team consisted of previously trained personnel: an undergraduate third year interior design student and interior design faculty members. Researchers visited the existing Browsing Room space, visually inspected and photo-documented lighting conditions in situ prior to a planned renovation. Researchers examined the existing lighting and reviewed associated architectural and electrical "as-built" drawings to determine light source types, wattage and other attributes. The "as-built" drawings showed that the library's last lighting remodel was in 1999 when the Browsing Room's current lighting was installed. The researchers also reviewed the existing lamps' cartons and consulted with the library administrators and resident Facility Manager to determine details and perceptions about the existing lighting system. The researchers took digital photographs via smartphones of existing conditions in the Browsing Room.

2.2 Empirical Field Study (Case study)

The researchers measured 0.61 meters or 1.22 meters square grids on horizontal room surfaces using masking tape to create a temporary grid as visual aids for taking regularly spaced lighting measurements. The researchers measured 0.61 meters increments from floor level upwards on vertical surfaces to create temporary grids. During multiple visits within a one week period, the researchers visited the selected interior social spaces and measured the existing illuminance levels in the evening following industry-recommended procedures. The researchers closed/lowered the existing window drapes and shades to prevent exterior lighting intrusion during the measurement of electric light (only) contributions.

2.3 Instrument

The researchers measured the electric light levels in footcandles (fc) on horizontal and vertical surfaces, using a Fisher Science Education Model #S90918 pocket digital light meter. Refer to Figure 1 for an image of the light meter in use.

Figure 1. Light Meter in Use

Refer to Figures 2 and 3 for photographs of the existing Browsing Room conditions.

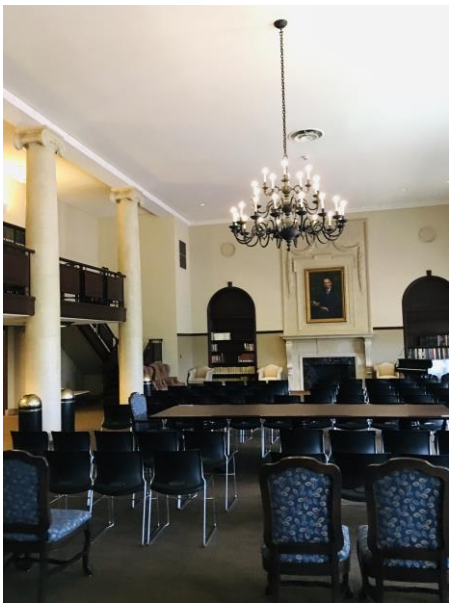

Figure 2. Existing Conditions with View of Main Area, LED Chandeliers, Mezzanine, Stairs, Fireplace Surround and Bookshelves

Figure 3. Existing Conditions with View of Main Area, LED Chandeliers,

Metal Halide Uplight Scoop Light Fixtures

After systematically taking and documenting multiple spot readings throughout each area according to industry recommendations, the minimums, maximums and means for light levels in each area

and task were calculated. Refer to Table 1 for the measured light levels by task and area. Light levels were converted to lux using an online calculator.

Table 1. Illuminance Levels in Library

	Main Area		Mezzanine		Stairs Treads & Landings (East)		Stairs Treads & Landings (West)		Fireplace Surround		Bookshelves	
Visual Task	Reading & Writing		Reading & Writing		Negotiating Stairs		Negotiating Stairs		Viewing (Aesthetics)		Reading (for book identification)	
Units	fc	lux	fc	lux	fc	lux	fc	lux	fc	lux	fc	lux
Industry Recommendations *	6.97-92.90	75.02-999.97	6.97-92.90	75.02-999.97	2.32-18.58	24.97-199.99	2.32-18.58	24.97-199.99	N/A	N/A	4.60-18.58	50-200
Means of measurements of existing conditions prior to renovation	2.4	25.8	2.9	31.2	0.5	5.4	0.2	2.2	1.2	12.9	0.5	5.4
Maximum measurements of existing conditions prior to	4.0	43.1	3.8	40.9	0.6	6.5	0.6	6.5	1.5	16.1	0.6	6.5

renovation												
Minimum measurements of existing conditions prior to renovation	1.5	16.1	0.8	8.6	0.1	1.1	0.1	1.1	0.6	6.5	0.4	4.3
Measurement prior to renovation complies with Industry Recommendations**	NO		NO		NO		NO		N/A		NO	
Means of measurements anticipated after renovation	10.42	110.22	16.30	175.45	3.94	42.41	3.62	38.75	N/A	N/A	5.25	56.51
Maximum measurements anticipated after renovation	15.80	170.07	26.40	284.17	8.50	91.49	6.90	74.27	N/A	N/A	7.60	81.81
Minimum measurements anticipated after renovation	4.80	51.67	10.30	110.87	1.80	19.38	2.00	21.53	N/A	N/A	0.90	9.69

Measurements anticipated after renovation complies with Industry Recommendations**	YES	YES	YES	YES	N/A	YES
Orientation of measurements	Horizontal	Horizontal	Horizontal	Horizontal	Vertical	Vertical
Height Above Finished Floor for measurements	0.762 meters AFF	0.762 meters AFF	0.762 meters AFF	0.762 meters AFF	0 meters AFF	Varies
Number of light level measurements taken before renovation and considered in renovation recommendation	104	40	40	56	56	52

2.4 Comparing existing light levels to standards

The researchers identified the current industry light level recommendations produced by the Illuminating Engineering Society (IES) for horizontal visual tasks (reading, writing and negotiating stairs) in areas occurring in the University Browsing Room (Main Area; Mezzanine; Stairs' Treads and Landings). Further, the researchers also measured and documented light levels for visual tasks on vertical planes (wayfinding, aesthetics, reading for book identification)) on the Fireplace Surround and Bookshelves. The researchers compared the existing light levels they had measured in situ to the industry (IES) range recommendations. Refer to Table 1 for a comparison of light level measurement means, maximums and minimums with industry recommendations. (Note that the lowest light level in the given ranges for industry recommendations in the table is the light level recommendation for younger adults and the highest number is the light level recommendation for older adults.) The researchers also noted compliance or non-compliance. Refer to Table 1 for compliance indications.

2.5 Consulting Standards

Researchers consulted published light level recommendations for various visual tasks [4]. They studied light source characteristics tables ([4], p. 13.2 – 13.5; [12], p. 15) to determine efficacy ranges for incandescent, metal halide and LED sources.

The researchers also consulted the 2009 Lighting Power Density (LPD) tables produced by the International Energy Conservation [18]; calculated and compared existing LPD in the Browsing Room.

2.6 Developing a Lighting Renovation Proposal

The researchers identified the industry light level recommendations produced by the Illuminating Engineering Society (IES) for horizontal visual tasks (reading, writing, negotiating stairs) in areas occurring in the University Browsing Room (Main Area; Mezzanine; Stairs' Treads and Landings). Researchers developed and proposed a retrofit to the existing lighting system. They partnered with a lighting manufacturer and utilized an existing LED catalog product, which was proposed for modification. Utilizing the manufacturer-provided photometrics for an LED wall sconce, a calculation was created utilizing proprietary software from the manufacturer. The wall sconces' lamp quantity and wattage determined as dictated to meet the IES recommended light levels. A layout was proposed for the new sconces while using only existing fixture rough-ins and the recommendation was made to replace the existing fixtures with new wall sconces one-for-one. 3DSM (Autodesk suite R17 software) was used to generate the photometric .x. plots shown in Figure 4. to map the anticipated light levels.

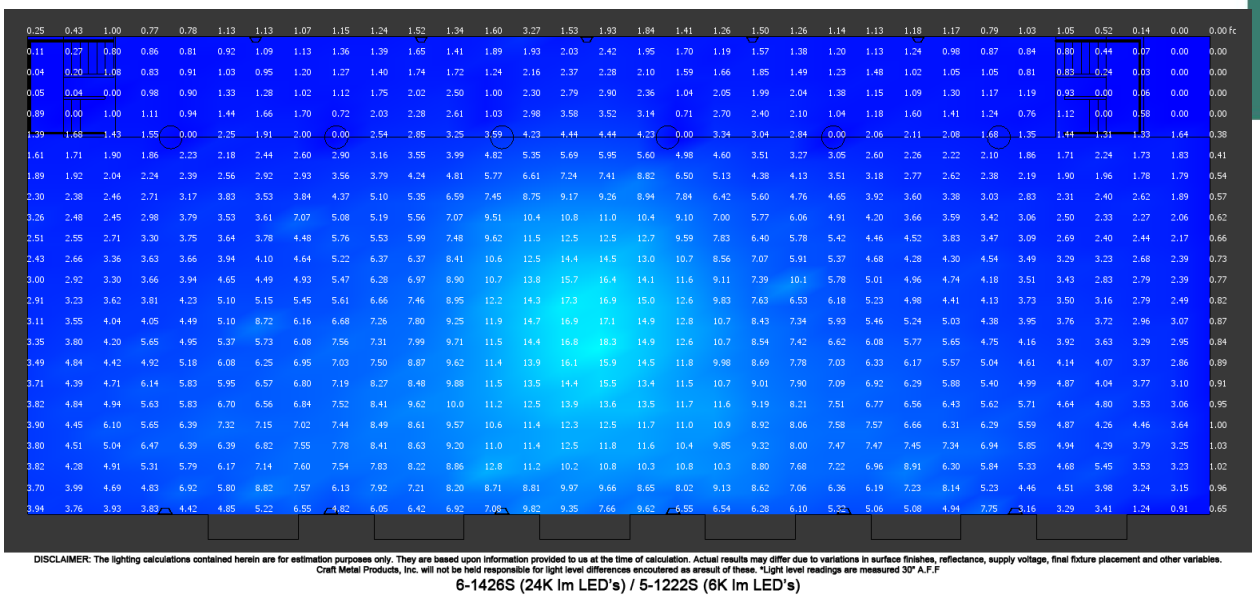

Figure 4. Light Plot with proposed new lighting (Courtesy of Craft Metal Products)

2.7 Comparing anticipated renovation proposal light levels to standards

The researchers compared the anticipated light levels to the industry (IES) range recommendations. Refer to Table 1 for a comparison of light level measurement means, maximums and minimums with industry recommendations. (Note in the table that the lowest light level shown in the given ranges for industry recommendations is the light level recommendation for younger adults (under 25) and the highest number is the light level recommendation for older adults (over 65). The researchers also noted compliance or non-compliance. Refer to Table 1 for compliance indications.

The researchers determined the lighting design proposal LPD in the Library Browsing Room by adding the wattage of the proposed new LED wall sconces and dividing by the square footage of the Browsing Room. They compared the anticipated LPD with the LPD standards.

3. Research results

3.1 Existing Conditions

3.1.1 Quantity, Wattage, Efficacy and Descriptions of Lighting

The study examined existing lighting within a University Library's Browsing Room. The researchers found that the existing Main Room lighting in the Browsing Room consisted of (13) uplight scoop light fixtures lamped with clear, 400 watt metal halide lamps. Refer to Figure 5 for a photograph of an existing uplight scoop fixture.

Figure 5. Existing Metal Halide Scoop Uplight

The scoop fixtures provided indirect illumination only. The indirect lighting had long been supplemented by (3) vintage, incandescent table lamps along the perimeter of the Main Area, which the library administrators wanted to retain. These lamps provided task lighting for some limited seating areas near the windows. Further, there were (2) existing, vintage, bare lamp chandeliers hanging from the main area of the Browsing Room, which had been recently re-lamped from incandescent to LED and which the library wanted to retain those table lamps. The Mezzanine contained (4) 175 watt metal halide uplight scoops with similar styling to those in the Main Area. Refer to Figures 2 and 3 for photographs of the existing Browsing Room lighting and Refer to Figure 5 for a close-up photograph of an existing up light scoop light fixture.

The efficacy ranges for the existing light sources and the LEDs being considered in the proposed renovation were found to be: incandescent: 8-13; metal halide: 68-120; and LEDs: 25-184 [11, 4]. Referring to the 2009 Lighting Power Density (LPD) tables produced by the [18], the researchers determined that the existing LPD in the Library Browsing Room's Main Area was 1.48 when considering the indirect metal halide scoop lights only. Even without considering the task lights and chandeliers, the existing conditions exceeded the 1.3 LPD currently allowed by code and therefore are not in compliance.

3.2 Empirical Field Study

The empirical study examined existing lighting levels in a University Browsing Room in situ. A total of 96 individual spot measurements were taken and compared to industry standards. Refer to Table 1.

3.2.1 Horizontal Surface Measurements

None of the (n=72) individual horizontal measurements and none of the light level means for the areas studied (Main Area, Mezzanine, Stairs' Treads & Landings East and West) for their associated visual tasks (reading, writing, negotiating stairs) were found to comply with the industry lighting recommendations for younger adults (0, 0%) or older adults (0, 0%).

3.2.2 Vertical Surface Measurements

None of the (n=26) individual vertical light level measurements and none of the light level means for the areas studied (Fireplace Surround and Bookshelves) were found to comply with IES lighting recommendations. "Fireplace surround" or its associated tasks (wayfinding, aesthetics) were not found to have any corresponding IES recommendations for comparison for the six measurements taken. For the Bookshelves and its associated tasks (Reading for book identification), none of the 20 measurements were found to comply (0, 0%) with industry lighting recommendations for younger adults (0, 0%) or older adults (0, 0%). Refer to Figures 2 and 3 for photographs of the fireplace surround and bookshelves.

3.3. Renovated Lighting Design Proposal

Based on the existing conditions as compared to industry standards, a renovated lighting design proposal was generated for the Browsing Room by the researchers in cooperation with the lighting fixture manufacturer. The renovation proposal included a modified LED wall sconce with a scroll design and a custom finish. The sconce featured a lensed face and asymmetric reflector. Refer to Figure 6 for a photograph of the renovated lighting with a view of the new LED wall sconces in the Main Area. Refer to Figure 4 for the anticipated Main Area light levels in photometric .x. plot. Refer to Table 1 for anticipated renovated light levels and compliance indications.

Figure 6. Renovated lighting in the Main Area with new wall sconces

According to International Energy, the allowable Lighting Power Density (LPD) for a library is 1.3. The researchers calculated the anticipated LPD for the proposed lighting renovation of the Browsing Room and compared the anticipated LPD in the proposed renovation to the allowed LPD. The new fixtures were 266.67 watts each and were 90 lumens per watt. The new fixtures contributed 0.98 lumens per watt, far lower than the 1.3 LPD allowed by code.

4. Recommendation

Although the researchers took some spot measurements with a light meter after the new lighting was installed, which appeared to confirm that the newly installed renovation lighting met the proposed illuminance, it is recommended that the Browsing Room be fully measured utilizing a light meter along gridlines to determine if compliance exactly matches the anticipated light levels in the proposal.

It was beyond the scope of this study to consider natural daylighting. A future study should determine the daylighting contributions across seasons and times of the day and consider using daylight harvesting technology near library building widows to save energy

5. Limitations

This is a case study pre-test and it considered only one library site and one Browsing Room. This research study considered only existing electric light contributions and was performed during a one week period without consideration of seasonal variations or weather variations over time. The existing building and electrical system

had some constraints since it was historic. A few of the existing lighting fixtures appeared to be malfunctioning at the time of the study.

6. Conclusions

Libraries are committed to providing support for various activities beyond merely reading printed material. Because of the needs of students, staff and other patrons, it is especially important to provide appropriate interior lighting spaces that meet the recommended illuminance levels for a variety of visual ages. Interior lighting in libraries should be designed to support library patrons in performing a range of visual tasks.

Based on a comparison to industry standards, the existing lighting levels did not meet illuminance recommendations. However, the recommendations are open to some interpretation. The University Browsing Room building examined in this study was over 60 years old and could benefit from a lighting renovation. The non-uniform illumination found at the library creates potentially problematic areas of high light level contrasts with glare and deep shadows in evidence. Some of the under-illuminated areas could benefit from supplemental lighting or higher lumen outputs.

This study demonstrates that in one facility, many of the existing light levels measured did not meet the recommendations for visual tasks in libraries. Less-than-recommended levels could result in reduced visual performance, safety issues and frustration amongst library end-users. This study is relevant because more in situ case studies are needed to increase the scholarly literature regarding illumination levels for University library Browsing Rooms. It is anticipated that supplementing future light level case studies with studies of students' and other library patrons' perceptions of their library environments' illumination will be helpful. The resulting lessons learned from this study could prove useful to authors of new lighting recommendations, designers of new facilities, and ultimately benefit library patrons and their resulting quality-of-life.

The proposed lighting renovation with LED light fixtures offered much higher lumens per watt than the existing metal halide uplights. The LED fixtures utilized modern optics to supply more light for visual tasks. It is anticipated that the new LED fixtures' styling will be perceived as more compatible with the historic Browsing Room interior.

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