Introduction

This white paper is intended to provide a general overview of quantitative and qualitative lighting design aspects.

Two foundational principles of lighting design guide most designers and architects – the **qualitative** (or aesthetic) aspect and the **quantitative** (or engineering) aspect of lighting design. The qualitative part pertains to ensuing that a space has a pleasing ambience. It is the artistic interspersing of shadows and light, darkness and illumination, highlighting figure and form.

The quantitative part revolves around providing adequate light for a space. The Illuminating Engineering Society (IES) publishes guidelines of light levels for many tasks and activities based on the nature of the space[1].

Qualitative Lighting

The qualitative lighting design component centers on the "quality" of the lighting, which is primarily driven by aesthetics and is largely subjective. The sources of subjectivity include the use of the space, architectural features, current trends, styles specific to the region the project is located, and even the personal preferences of the occupants of the space. For example, the quality of the lighting design in an automotive factory would be far from appropriate for an art museum.

The level of subjectivity necessitates that a lighting designer be familiar with art, psychology, and human physiology. Armed with these backgrounds, a lighting designer can carefully balance the artistic component, psychological component, physiological component, and quantitative lighting design component to create a design that is both functional and aesthetically appealing to a majority of the occupants. This combined approach may result in lighting designs that incorporate luminaires for general ambient lighting, luminaires for accent lighting, to create highlights and shadows for visual interest, and luminaires for task lighting.

While a majority of the qualitative lighting design component is subjective, there are several points that can be measured.

Glare

Glare is a measurable aspect of lighting design which can have a negative effect on the physical well-being of occupants including headaches, neck and shoulder pain, and eye fatigue resulting in sore, red, and itchy eyes. Glare can also have a negative impact on the individuals work performance, their mood and motivation, and the amount of sick leave a person takes.

Common examples of such situations leading to discomfort (glare) include headlights of oncoming vehicles when driving after dark and direct sunlight through the windows in daytime.[2]

The Illuminating Engineering Society (IES) recognizes two types of glare.

Discomfort glare is caused by light sources in the occupant's field of view, resulting in annoyance or pain. Discomfort glare can include an intense light source that is directly observable from an occupant or a light source in the occupant's periphery.

[1] Intro to Lighting Design: Qualitative & Quantitative Principles – Language of Lighting, Staff Writer, April 6, 2020
[2] Measuring Discomfort from Glare: Recommendations for Good Practice – energy.gov

Disability glare is caused by light scattered within the eye, reducing contrast and thereby reducing visibility. An example of disability glare is bright sunlight coming through a window blinding you.

The effects of glare can be estimated and minimized by a savvy lighting designer.

Color Rendering Index (CRI)

Color rendering index, or CRI, is a 0 to 100 scale that indicates how accurately an artificial light source renders colors relative to natural sunlight, which is considered to have a CRI of 100. The closer an artificial light source's CRI is to 100, the closer those colors will look when compared to those colors being placed under natural sunlight. Conversely, the closer an artificial light source's CRI is to zero, colors and contrast will appear nearly nonexistent.

An artificial light source with a CRI of 70 to 80 is generally considered acceptable while a CRI of 90 or more is generally considered excellent. A CRI less than 70 is generally considered poor because distortions in colors become readily apparent.

The use of a space plays a role in selecting the proper CRI because light sources with a high CRI come at increased cost and will typically reduce the illumination the light source can provide. For example, light sources with a CRI of 80 to 90 are generally considered acceptable for a typical office space, because precisely rendering colors is not necessary. However, an art museum that is highly dependent on precisely rendering colors would require light sources with CRIs much closer to 100.

Therefore, the measurable (quantitative) CRI value plays a role in the qualitative lighting design component for two reasons:

1. It is generally considered that a low CRI will not appeal to a vast majority of the population
2. The use of the space may suffer if the CRI of the light sources within the space are not appropriate.

Correlated Color Temperature (CCT)

The correlated color temperature (CCT) of an artificial light source can be explained as an indicator of how yellow or how blue the light emitted from the light source is. Color correlated temperatures of artificial light sources generally fall between 2,200 degrees Kelvin (K) and 6,500 degrees K. The lower the CCT, the more yellow (or warm) the light is, while a higher CCT indicates a more blue (or cool) light.

Choosing the correct CCT is very important in enhancing the theme for the space. For example, a space employing light sources with a CCT that is

- approximately 3,000 degrees K is generally considered warm, inviting, and comforting.
- approximately 4,000 degrees K is generally considered to be energizing and invigorating.
- greater than 4,500 degrees K is generally considered to be stark and sterile.

For reference, a blue sky has a CCT of approximately 10,000 degrees K.

Although CCT is a measurable (quantitative) metric, it plays a role in the subjective, qualitative component of lighting design because failure to recognize the use of the space could completely change an occupant's perspective about that space.

Uniformity

The uniformity of the illuminance throughout a space can be measured using uniformity ratios. These ratios compare maximum illuminance to average illuminance, maximum illuminance to minimum illuminance, and/or average illuminance to minimum illuminance. These ratios can provide a telling story on whether the lighting effects are appropriate for the intended use. For example, an average to minimum uniformity ratio of 5:1 is generally considered acceptable for the general lighting within a typical office space. However, in a space where shadow play and highlights are important for the space's aesthetic, a much higher uniformity ratio would be appropriate.

Quantitative Lighting

The quantitative lighting component involves performing calculations in an effort to achieve a target lighting level (illuminance) within the space. These calculations are called photometrics and are based on numerous variables, which include:

- the rated lumen output of the light sources;
- the quantity of light sources;
- the physical locations of the light sources;
- the physical dimensions of the space;
- the distance between the light source(s) and the work plane;
- the distance between the light source(s) and the ceiling;
- the proportion of the perimeter of the space to the distance between the light source(s) and the work plane;
- the reflectance's of the walls, ceiling, and floor; and
- light loss factors, which include twelve sub-factors.

Performing these photometric calculations manually is tedious and laborious, especially in large facilities with several types of space uses. Luckily, computers have come to the lighting designer's rescue with the advent of software packages and plug-ins including AGi32, CalcuLuX, DIALux, Radiance, Microlux, Lightcalc, and Visual. Many manufacturers also offer web-based photometric tools.

The lighting designer will input all the aforementioned data into the software and also select a target lighting level (illuminance). The illuminance target that the lighting designer selects is typically rooted recommendations published by the Illuminating Engineering Society (IES). From there, the software takes over and calculates the illuminance on a grid of points, which the lighting designer will use to evaluate how close (or how far) the calculated illuminance values are from the target and how uniform the lighting is throughout the space. While it appears this may be a trial-and-error method, an astute lighting designer will typically be able to get near the targets without rework.

Conclusion

In conclusion, lighting design is a complex and multifaceted process that requires a unique combination of artistic vision and technical expertise. Without a thorough understanding of both qualitative and quantitative components, a successful lighting design cannot be achieved. At Light Plan Design, we have the expertise and experience to bring your vision to life. Contact us at to discuss how we can help you achieve your lighting design goals. Let's work together to create a space that is both functional and beautiful.

About Bonny:

Bonny Whitehouse, Director of Lighting Design, is dedicated to developing creative, state- of-the-art, energy efficient lighting solutions, in keeping with the rapidly evolving lighting and control technologies and budgetary constraints of our clients. She stresses the importance of the innovative application of creativity while recognizing technical standards and the needs of end users. She is sensitive to the needs and requirements of the built environment, and works closely with other trades to deliver an integrated design to our clients.

Bonny received a Bachelor of Science in theatrical design. While attending NYU for her Masters of Fine Arts, she worked on various Off- Off Broadway and Off Broadway shows.

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Jason Rohe, P.E. has been involved in the design of electrical systems for malls, mixed-use developments, corporate offices, national retail rollouts, schools, hospitals, medical facilities, commercial and institutional buildings for over 25 years with Schnackel Engineers.

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