DESIGN GUIDE:
INCORPORATING CIRCADIAN-EFFECTIVE LIGHTING INTO THE INTEGRATED DESIGN PROCESS

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INTRODUCTION

Circadian-Effective Lighting

Humans have a biological master clock in the brain that regulates behavior and physiology according to a cycle of approximately 24 hours. A consistent and regular 24-hour cycle of light and darkness at the eye synchronizes the master clock to each person's local position on Earth. This day-after-day synchronization of a person's physiology and behavior to the local light-dark cycle is known as circadian entrainment, enabling people to perform their many biological functions consistently at the right time every night and every day and maintain good health.[4]

Circadian-effective lighting provides daytime light levels that are high enough, for a sufficient period of time (i.e., at least 2 hours per day, preferably during the morning), to support circadian entrainment for building occupants. To be effective, these high daytime light levels should be coupled with the provision of dim light levels at night. Circadian-effective lighting has been shown in numerous studies to improve sleep for building occupants at night and reduce their sleepiness during the day.[4-6] The US General Services Administration (GSA) P-100 Facilities Standard calls for the provision of circadian-effective lighting in the design of new and substantially renovated public facilities.[7]

The Integrated Design Process

The Integrated Design Process (IDP), also known as Integrated Building Design (IBD), Integrated Project Delivery (IPD), or a host of similar names, is a collaborative approach to building design and construction that considers the entire building and its systems. IDP involves multiple disciplines working together from the beginning of a project to achieve optimal outcomes for the client and ultimately, for building occupants.[1] The use of IDP in the design and construction of buildings has been growing over the past 25 years. This has been spurred on by the growth of interest in green, or sustainable building design, which encourages the use of IDP in its projects. IDP has been shown to provide several beneficial outcomes in the building process. These include improved construction quality, lower costs, reduced construction delays, better environmental performance, and overall improved value for the client.[2,3] It is also critical to the success of IDP that integrated design teams have an effective leader who will regularly facilitate interaction and communication among team members from inception to completion.[10]

A collaborative IDP can also be beneficial in the development of a circadian-effective lighting design and installation. However, to ensure that a completed building project is optimized for circadian-effectiveness, it is important that each member of the design team understands their role in the process of designing circadian-effective lighting, and how the decisions they make can impact the circadian effectiveness of the final building design. The purpose of this guide is to examine the roles and responsibilities of each member of the integrated design team in the process of developing a circadian-effective lighted environment, and review how the decisions each team member makes affects design outcomes in terms of their circadian-effectiveness.

DESIGN TEAM MEMBERS

The composition of integrated design teams varies widely based on the scope, size, and complexity of a particular building project. More complex projects, such as a new office campus, will often require teams with multiple members representing a wide range of design and construction disciplines. Less complex, design-build projects, such as the renovation of an existing office building, may have integrated design teams that include only a few members. This guide illustrates the composition of integrated design team members for a large building project, and will focus on those members whose responsibilities and decisions are likely to impact the circadian effectiveness of the lighted environment for building occupants.

Figure 1 illustrates core members of the integrated design team whose work will impact the circadian effectiveness of the lighted environment for building occupants. Each team member is included within the design phase where their work will have the most impact on circadian-effective lighting design and implementation. However, all team members listed need to work together in all phases of the IDP for the final circadian-effective lighting project to be successful. Many integrated design teams are managed by an architect or project manager who oversees the project, coordinates communication and collaboration among team members, and communicates with the client, whose input plays a pivotal role in all phases of the IDP. Effective project leadership is crucial to the success of the IDP.

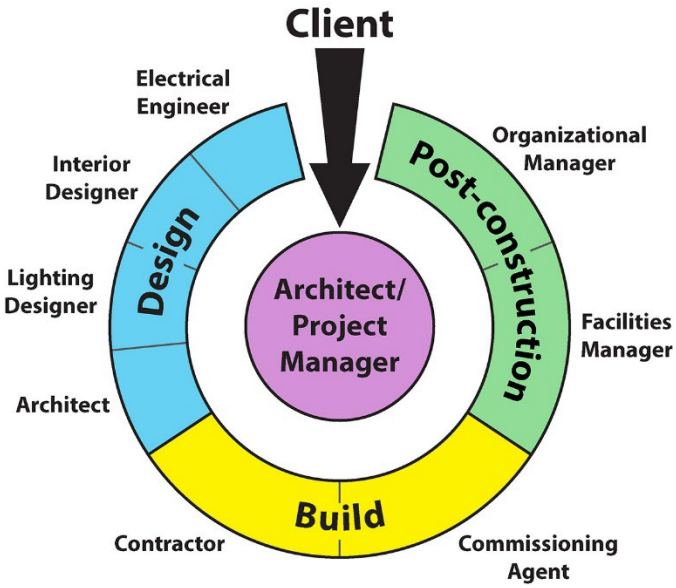

Figure 1. The integrated design process, the three phases and team members important to design and implementation of circadian-effective lighting.

Although one position is listed for each team member, it should be understood to also include other staff within that person's office or firm, as well as subspecialists, such as energy modelers, who might assist in the building design. All integrated design teams are different. Table 1 lists members of the integrated design team example with their responsibilities in the circadian-effective lighting design process. Because the responsibilities of team members will vary and change based on the type and complexity of building projects this table should only be considered as an example of a team's composition and responsibilities.

Table 1. Integrated design team members and their responsibilities in the circadian-effective lighting design process.

Team Member	**Examples of relevant responsibilities**
Architect	Building siting, orientation, design; daylighting; team leader, project coordination
Client/end user	Building owner, developer, end user representative
Commissioning agent	System set up and commissioning
Contractor/builder	Procures materials, manages construction and subcontractors, quality control
Engineers	Building structure, electrical systems, mechanical systems, environmental systems, IT systems, fire prevention systems
Facilities manager	Manages building systems, post-construction
Interior designer	Interior colors and finishes, furnishings, layout, window shades/blinds
Landscape architect	Exterior features, landscape
Lighting designer	Electric lighting and lighting controls; daylighting
Organizational management	Manages building occupants and operation, post-construction
Project manager	Project coordination, scheduling, oversight

IMPACTS OF TEAM MEMBER DECISIONS ON CIRCADIAN-EFFECTIVE LIGHTING

Each of the integrated design team members listed above could have an impact on the circadian effectiveness of the final design, although some will have a much more significant impact than others. This section of the guide will review the roles and responsibilities of each team member and discuss how their design decisions could impact the work of other members of the team, and, ultimately, the circadian-effectiveness of the final design.

Programming

To begin the building project, the client and the architect meet to define the scope of work, identify the needs of building occupants, and define other building characteristics. This phase in the design process is typically referred to as programming.

Architect

The architect is often the leader of the integrated design team, and their office may also be responsible for managing the overall design and construction process. As such, they play an important role in ensuring that the contributions from various team members are well coordinated. They are also directly responsible for several design decisions that will have important impacts on the circadian effectiveness of the final design. These include:

Building configuration, siting, and orientation

In most modern buildings, daylight is an important contributor to ensuring circadian-effective lighting for building occupants. A building's configuration, its siting, and its orientation all play important roles in optimizing access to daylight for building users. Control of a building's configuration, siting, and orientation is typically only possible for new construction projects. When a design project encompasses the renovation of an existing structure, there is little or nothing an architect can do to alter the configuration or orientation of the building itself, only its interior spaces. In new construction, however, a building's design configuration, siting, and orientation play important roles in maximizing access to daylight for interior building spaces.

For new construction, architects are usually presented with a site on which they must locate and orient the building. In some locations, such as an inner-city lot tightly surrounded by existing buildings, they may have little choice as to the building's location on the site or how its facades are oriented. In other instances, such a large lot in a more rural area, they may have many options for the building location and orientation on the site.

To optimize access to daylight for interior building spaces, a building should be oriented so that its maximum facades face south and north, while minimizing east and west exposures. During almost all times of the year, north-facing windows receive light from the sky rather than the direct sun, resulting in soft, even illumination throughout the day. South-facing windows capture the most sunlight, providing ample daylight, particularly in winter. However, design measures, such as exterior shading devices or other building design strategies must be employed to defuse direct sunlight entering through south-facing windows, or building occupants are likely to close interior blinds or shades for a significant portion of daytime hours. East and west facing windows can be challenging for consistent daylight and glare control.

Assuming a rectilinear building design, it is optimal to keep the building narrow, when possible (for example, a maximum floor depth of 60 feet along the building's north/south axis). This helps to maximize the penetration of daylight from windows into interior building spaces.

Building fenestration

Architects typically are responsible for selecting building fenestration. These can include windows, skylights, roof monitors, or other structures through which daylight will penetrate into interior spaces. The design and selection of building fenestration and glazing materials should be coordinated with engineers and modelers responsible for the

building's structural, mechanical, and environmental systems. However, there are a few rules of thumb that an architect should keep in mind to maximize daylight in a building.

- Maximize window area along the south and north façade. These will be most effective at bringing daylight into interior spaces. While architects must work with engineers and energy modelers to optimize window to wall area ratios to limit heat gain and loss, they should configure windows to bring daylight in high; tall or clear story windows are most effective at allowing daylight to penetrate deeply into a space while allowing it to bounce off interior surfaces. As stated above, on the south façade design measures should be taken to diffuse direct sunlight entering through windows.
- Select glazing materials for windows and skylights that maximize daylight penetration and minimize heat gain. There are many options for high performance glazing materials that minimize heat gain from windows during the summer months. Also remember that window tints or films will never fully prevent glare from direct sunlight; other strategies must be considered to limit sunlight glare, such as interior window blinds or external shading devices.
- Consider top-lighting strategies. Skylights, roof monitors and other top-lighting strategies are very effective at bringing daylight into buildings. Always consider these strategies when designing single story buildings or on the top floor of buildings (Figure 2).

Figure 2. This school building employes south-facing roof monitors and deep-set windows with light shelves to provide daylight to classrooms but limit glare from direct sunlight.

- Protect occupants from glare. Building occupants typically like windowed spaces, not just because of daylight, but also because windows allow a view and connection to the outdoors.[11] In fact, research has shown that people will even tolerate some glare from direct sunlight, if the view is worthwhile.[11] Unfortunately, in many cases one of the unintended consequences of windows or skylights can be glare. Architects should consider building design approaches, such as exterior shading structures or window configuration strategies along the south façade that help to block direct penetration of sunlight into interior spaces. For skylights and south facing roof monitors, glare reduction strategies such as skylight interior well configurations or the use of baffles should be considered.
- Direct sunlight can be an attractive feature in transitional spaces such as corridors, lobbies, or in break rooms where people can easily move to avoid the glare. However, in building spaces where people are working for significant periods of time throughout the day, south, east, and west facing windows will often need interior blinds or shades that building occupants can adjust as needed to limit view of direct sunlight that might be uncomfortable or negatively impact the visibility of their tasks. These interior shading systems should be selected carefully, in coordination with the interior and lighting designers to ensure they meet the needs of occupants, while still allowing daylight into the space to the maximum degree possible.

Client/End User

Both the design client and a representative of the entity that will ultimately occupy the building, if different from the client, play crucial roles on the integrated design team, during the building design process. It is their input that should primarily shape and drive the design team decisions. Ultimately, buildings are designed for the people that will occupy and use the spaces on a daily basis. So, it is important for design team members to all be aware of the goals, objectives, needs, and desires of the end users of the buildings when they are making design choices. Design goals and objectives should be clearly defined at the outset of the project and team members should always be able

to refer back to these when making design decisions. This is important when designing circadian-effective lighting. Some of the input needed from building end users includes:

- Worker schedules – Will occupants of the building work daytime schedules, or do they work on shifts throughout the day and night? Are shifts static, or do they rotate and change over time? What are typical start and end times of each shift? How many days per week do workers typically come into the building? Are these days the same each week, or do they change? This information will be important for design team members who are tasked with setting lighting and control schedules for a circadian-effective lighting system.
- Worker tasks – What types of tasks do workers in the building typically perform? Are tasks different in different spaces, or uniform throughout the building? What are the orientations of occupants with respect to their tasks? Are tasks in a vertical plane, such as looking at a computer screen? Or do tasks have a horizontal orientation, such as reading print on paper, or assembling products on the work surface? Do workers do the same tasks each day, or do tasks change over time or throughout the week? Because lighting must reach the eye of the building occupant to be effective for the body's circadian system, task type and orientation will affect how the lighting is designed to meet the needs of workers.
- Worker locations – Where in the building do workers spend most of their day? Are worker locations static, or do workers move to different spaces through the workday? Do workers have assigned workstations, or do they select a different station each time they come in? Information about the location of building occupants at different times of day is important to ensure that the timing and duration of light is properly scheduled to provide circadian effectiveness.

Design

The next phase of a building project is design, and typically involves the following professionals:

Engineers

Modern buildings are built with numerous complex systems including heating ventilation and air conditioning (HVAC) systems, IT systems, electrical, and fire prevention. Some of these systems have components that may interact with the lighting, lighting control, or daylighting systems. For example, engineers must all coordinate the location of system components so that all team members, including other engineers, lighting, interior designers, and architects are aware of their locations. If the design and location of these systems are not well coordinated, situations will occur where one system component conflicts with the location of another. For example, Figure 3 shows overhead conduit, necessary for the electrical and IT systems, nearly partially blocking a skylight. In this situation, the location of the skylight was determined by the lighting designer or architect, who were unaware of the conduit which was added to the design at a later time by the electrical engineer.

Figure 3. Electrical conduit blocks light from a skylight in this office building.

Complex, whole-building control systems are also becoming more common. These systems integrate the operation of several building systems including lighting, electrical, and HVAC. This is done to improve the overall operating efficiency of these sub-systems, allowing them to respond to events, such as variable time pricing or power shortage signals from the electrical utility. Lighting designers and engineers must coordinate both the specification and set up these systems to help ensure that parameters that can affect the circadian-effectiveness of the lighting such as the timing and duration of lighting adjustments or the amount of light provided by the lighting system are taken into account and appropriate control decision hierarchy is agreed upon.

Interior Designer

The interior designer has a significant impact on the circadian-effectiveness of the lighted environment in the building, although, the importance of the decisions made by interior designers in regard to circadian-effective lighting is often overlooked. Interior designers work with architects and other team members to design and configure interior spaces, select furnishings, and specify finishes for surfaces throughout the building. They are also typically responsible for making final decisions on window coverings such as blinds or shades. All of these items will affect the amount and distribution of the light that ultimately reaches the eyes of the building occupant. Therefore, the interior designer must work closely with the other integrated design team members so that all decisions made by the team members go hand-in-hand. Important decisions made by the interior designer that will affect the circadian effectiveness of the lighting include:

Figure 4. Interior walls of this historic office building are kept light colored to reflect daylight from the large windows.

- Interior colors and finishes – Daylight and the light that exits a luminaire immediately interact with other surfaces in the space. When light lands on a surface, it is either absorbed by the surface, travels through it, or is reflected off the surface. The color and finish of each surface impact how light will interact with it (Figure 4). Lighting designers must know surface characteristics to be able to properly model a lighting and daylighting design. This is a crucial step in the design of circadian-effective lighting.

  Manufacturers of most commercial grade paints, fabrics, and other interior surface products will publish the reflectance values for their products, normally as a percentage. For a diffuse surface, the lighter the color of the surface, the higher the reflectance will be. A reflectance of 80%, for example, means that the surface will reflect 80% of the light landing on the surface.

  There is a saying in the lighting design profession that a white wall is the most energy efficient. However, painting every surface in a space white might make for a very boring space. Therefore, interior designers, architects, and lighting designers should work closely together to select surface characteristics that effectively reflect light, while still meeting other design parameters. The lighting designer will then use this information to ensure that the lighting model they develop is as accurate as possible.

- Furniture selection and placement – A rule of thumb in daylighting is “move people to the light.” With electric lighting, it can be said “move the light to the people.” Furniture selection and placement significantly affects how effectively one can move people closer to available daylight. For example, in an open-plan office with windows where cubicles are specified, it is important to keep furniture partition heights low to allow the daylight to travel from windows deep into the space. It is also important to orient the view direction of the workers toward the windows. Both strategies will help to bring daylight to the eye of building occupants where it can provide the greatest circadian impact. Furniture, such as office cubicles, also provides opportunities to integrate electric lighting directly into it, so that lighting can be brought close to the occupant. Therefore, the integrated design team should work closely together to select furniture that can allow for electric lighting integration.
- Interior space configuration – Another important aspect of interior design is determining the use and configuration of interior spaces. If daylight in the building is limited, can spaces be configured so that building occupants spend most of their day in well lighted spaces? Can a well lighted space, with high circadian-effective light levels, be set aside for staff to go to during breaks and for meetings and interactions with fellow building occupants for periods of time during the day? Such a space could serve as a “circadian oasis” where staff who typically work in spaces where light levels are lower, and not circadian-effective, can go to be

exposed to circadian-effective light (Figure 5). In offices where staff do not have assigned workstations, can circadian-effective light always be provided? The interior designer, architect, and other team members responsible for interior space design and configuration should work with the lighting designer to discuss how each space will be configured and used. This information will be important for providing spaces where circadian-effective lighting can always be available.

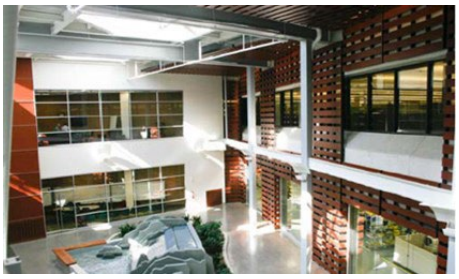

Figure 5. A building atrium with skylights and large exterior windows can provide a circadian "oasis" where employees can go to be exposed to high daylight levels.

- Window shade/blind specification – The interior designer and other team members who are involved in the selection and specification of interior window coverings should work with the lighting designer to provide information on the light transmission of these coverings. In spaces where people work throughout the day, some type of operable window covering will likely be required on all window orientations, with the possible exception of the north. These will allow the building occupants to block direct sunlight during periods of the day when it is falling on the windows. It should be emphasized that window tinting will never effectively block direct sunlight, so the use of window tints alone is not an effective strategy for providing circadian-effective light to occupants. Lighting designers should be involved in the selection of all window coverings, so that they can include this information to develop circadian-effective lighting in each space.

Lighting Designer

The lighting designer will have primary responsibility for ensuring the implementation of circadian-effective lighting as part of the design. It is their responsibility to take the input and information provided by all of the other team members and include these into their lighting design process. The lighting designer will also need to be an advocate with team members overseeing other building design decisions to ensure that considerations that can affect the circadian-effectiveness of the lighted environment are discussed and taken into account when making design decisions. Steps in the lighting design process will include:

- Information gathering – The first step in the lighting design process will be to gather information from the client/end users and ensure that there is buy-in from them and the team on the importance of circadian-effective lighting design to the project. Conduct a client assessment. Ask questions that will provide the information will be needed to prioritize spaces, set schedules, and develop designs for circadian-effective lighting. This step may take education and advocacy on the part of the lighting designer to help the architect, the client and other team members understand the importance of circadian-effective lighting to the health and well-being of building occupants. Other team members should also know how decisions they make might affect the circadian-effective lighted environment of the building.
- Conceptual lighting design – The conceptual lighting design for the building should lay out the spaces where it will be important to provide circadian-effective lighting, as well as the timing and duration of the light, and how it might change throughout the day, based on the needs of building occupants.
- Lighting design development – To develop a circadian-effective lighting design, follow P-100 Facilities Standard based upon the process laid out in *UL-24480 Design Guideline for Promoting Circadian Entrainment with Light for Day Active People.* More information on *UL-24480 Guideline*, and many additional educational resources about its use can be found online:

https://www.light-health.org/education/resources/ul-design-guideline-24480

An important part of design development will be to build a computation model of the lighting design for each space in the building. This should be done using a photometrically accurate software program such as AGi32 or DIALux.

It is important that this computational model includes both daylight and electric light as well as the furnishings because it should be as accurate as possible, considering all factors that could affect the final amount and distribution of light in the space. As part of this process, the lighting designer will also need to use the online *Circadian Stimulus (CS) Calculator* tool to help select the light sources that will work best in the design.

https://cscalc.light-health.org/

During this stage in the design process, it will be important for the lighting designer to "think beyond the ceiling." Ceiling mounted light fixtures are not the only means to provide circadian-effective lighting. Sometimes it can be most efficient and effective to include lighting that is either integrated into workstations or furniture (Figure 6) or consider portable light fixtures that can be used to augment the ambient light in the space. The lighting designer will need to be creative and consider multiple lighting options during the lighting design development process.

Figure 6. An example of circadian-effective light integrated into a cubicle in an open plan office.

Control strategies should also be considered that could be used to vary light levels throughout the day. The *UL-24480 Guideline* calls for the provision of circadian-effective light for a minimum of 2 hours per day, preferably in the morning. Because lighting energy use is also an important consideration in any design, an automated control system could be specified to provide higher, circadian-effective light levels during this 2-hour period (e.g., from 9:00 AM to 11:00 AM each morning), then lower light levels during the other hours of the day. It will also be important to coordinate this control strategy with other automated control settings including occupancy and daylight dimming control to ensure that circadian-effective light levels are not compromised by these other automated control settings.

The lighting designer must also navigate and ultimately resolve any conflicts that arise between the recommendations of the *UL 24480 Guideline* for circadian-effective lighting and other codes, guidelines, recommendations, and standards required to be met by the design team. This could include lighting power density (LPD) limits and prescriptive control requirements found in energy codes, light level recommendations found in lighting design recommendations published by professional bodies such as the Illuminating Engineering Society (IES) and design guidelines such as Leadership in Energy and Environmental Design (LEED) or other "green" building or "wellness" standards. In a GSA project following the requirements of the P-100 Facilities Standard, there is a conflict resolution process that allows for a design team to seek a waiver where requirements conflict. For more information on these potential conflicts, see ***Technical Report: Codes and Standards That Can Conflict with Circadian-Effective Lighting in GSA Buildings***.

- Design Documentation – Once the lighting designer completes the design, it is important they document the circadian related components of the design to ensure that the contractor, commissioning agent, and facility manager understand how the system should be installed, set-up, commissioned, and operated. Circadian-effective lighting is a new concept, and everyone may not understand why, for example, vertical illuminance at the eye of the building occupant is an important measure for the set-up and commissioning of the lighting. This must be clearly laid out in design documentation to ensure that design intent is not compromised.

Landscape Architect

The work of a building's landscape architect has less impact on the circadian effectiveness of interior building lighting. However, if there are going to be trees, plantings, or other exterior features near windows (Figure 7) that

might occlude or reduce the amount of daylight entering the windows, the lighting designer needs to aware of these, so that this information can be including in the lighting computational model being developing. Plantings near windows should be kept low, whenever possible, to avoid blocking daylight. Light-colored ground cover materials can also be used near windows to reflect more daylight from the ground up into windows and thus into the building interior.

Figure 7. Plantings near the windows of this office building are kept low so as not to block daylight into the interior and light-colored groundcover is used near windows, which reflects daylight.

Part of a strategy for the provision of circadian-effective lighting, especially in more temperate climates, might also be to encourage staff that work in more dimly lighted interior spaces to spend a period of time outdoors at the same time each day. Therefore, the landscape architect might be able to plan outdoor work areas, walking paths, or other features that would both accommodate and encourage building occupants to spend some of their workday outdoors.

Build

Once the design phase is complete, building can begin. The team members typically involved in this phase include:

Project Manager

The project manager is often the central coordinator of the integrated design team, managing the schedule and budget, and facilitating communication among the various disciplines. The project manager is also often in charge of managing any changes that happen during the design and construction process, and sees the project through to commissioning and the hand over to the client. The project manager must be well-informed about the components of the project that could affect the circadian effectiveness of the completed building including daylighting, electric lighting, control, and other environmental factors. When changes are made in these areas during the design and construction phases the project manager must inform the architect and the lighting designer to discuss potential impacts to the circadian-effective lighting design. This will allow the lighting designer to consider changes, where needed, coordinate these changes with other team members, and allow the project manager and others to assess the impact of these changes on the overall design.

Contractor/builder

In a design-build project, the contractor or one of their employees might then be responsible for team coordination. The contractor's primary responsibility, however, is to manage the construction process, including procuring building materials, managing subcontractors, and other tasks involved in the building project. There are several ways in which decisions made by the contractor can affect the circadian-effectiveness of the final, as-built design. These include:

- Building design/structure – During construction, changes may be made to the building structure to accommodate unforeseen circumstances. These changes may force the alteration or relocation of windows, skylights, lighting, or lighting control components. Other design team members such as the lighting designer, interior designer, and architect must be aware of these changes, be able to assess their impact on the daylight or electric light that will be provided for building occupants, and make suggestions for changes needed to the overall design.
- Product substitutions – Product changes often occur during the building process. This can be due to number of factors including cost or unavailability of specified products. If changes are made that affect the daylighting,

such as changes in glazing materials, daylight contributions may need to be recalculated by the lighting designer or engineer. Similarly, changes in lighting or lighting control products could require that the lighting designer recalculate lighting contributions and make adjustments to the design to ensure that parameters affecting the circadian-effectiveness of the design are taken into account.

- Interior furniture and finishes – Changes to interior furnishings and finishes will affect light levels in the space. Therefore, if changes in these parameters are needed during construction, the lighting designer, interior designer, and other team members may need to adjust the design to accommodate these changes.

Commissioning Agent

In this guide, the commissioning agent is defined as the person or people who are responsible for the set-up and for final testing of building systems to ensure that they are operating as intended, prior to final building occupation. In many situations, the set-up of systems might be done by the team members who have designed each system, or in collaboration with representatives of the manufacturer of each system. Final testing and troubleshooting of systems might be done by an independent, third-party commissioning contractor. In any case, it is crucial that these agents have complete and detailed information about each factor that will affect the final design intent of the lighting and daylighting systems.

For example, when setting up or commissioning the lighting and lighting control systems it is typical to adjust the lighting controls (Figure 8) to provide a specified, minimum horizontal illuminance on each work surface, for example, 300 lux. However, circadian-effective lighting requires a minimum vertical illuminance at the eye of the user at a specified time of day, for a specified duration. Commissioning agents must be made aware of this, so that they can ensure that the lighting system is properly set up to provide these specified parameters. These lighting parameters (timing, amount, and duration of light) must be clearly spelled out in the commissioning documents, along with the appropriate measurement location (i.e., vertically at the eye level of the building occupant) for each building location/task site.

Figure 8. A commissioning agent makes adjustments to a lighting control device.

If specifications conflict, for example if providing circadian-effective vertical illuminance to the eyes of the building occupant requires that the lighting system provides a higher than specified horizontal illuminance on the work surface, it must be made clear in commissioning instruction how these conflicts should be addressed. This might include, for example, instructions that the lighting control system should be commissioned to provide the higher overall light levels for two hours each morning (e.g., from 9:00 AM to 11:00 AM) and then adjusted to provide a lower light level that meets minimum horizontal illuminance requirements for the remainder of the day.

It is often the set up and commissioning of a lighting system that compromises circadian-effectiveness. This is most often due to a lack of information provided to the set-up and commissioning contractor(s), or a lack of understanding on their part of the steps they need to take to ensure that the lighting is circadian-effective. Good instructions and communication with these team members are crucial for ensuring that the building occupants receive circadian-effective lighting as intended. The architect or project manager should ensure that this communication happens effectively.

Post construction

Once the building is complete, it is handed over for occupancy. The team members who have the greatest impact on the overall functioning of circadian-effective lighting during this occupancy period are included below.

Facility Manager

Once a building is built and handed over to the people who will occupy and use the spaces on a daily basis, most members of the integrated design team will no longer be involved in its operation. It then primarily falls to the building's facilities staff to ensure that building systems continue to operate as designed. Facilities managers play a very important role in maintaining the integrity of the design, while ensuring that the building meets the needs of its occupants. They are often the ones required to balance such factors as occupant satisfaction, energy efficiency, environmental and building performance. These factors include building daylighting, electric lighting, and lighting control system operation.

It is important that facilities managers are part of the integrated design team from the inception of the project through to completion. If this is not possible, it falls to the architect or project manager to ensure that important information about the operation of building systems is effectively communicated to facilities management professionals.

Facilities staff have experience and insight that will provide crucial information to the integrated design team as they design, build, and commission the building. They are aware of the needs of occupants and how these occupants typically interact with building systems, including complaints the occupants most frequently have had about the operation of previous buildings. It is also these facility staff who will be operating the building going forward. They must know how all of the systems operate and can be adjusted (Figure 9), especially control systems. They should also be involved in the set-up and commissioning of the lighting and lighting control systems to provide input into the process and learn how to set-up and adjust the system components.

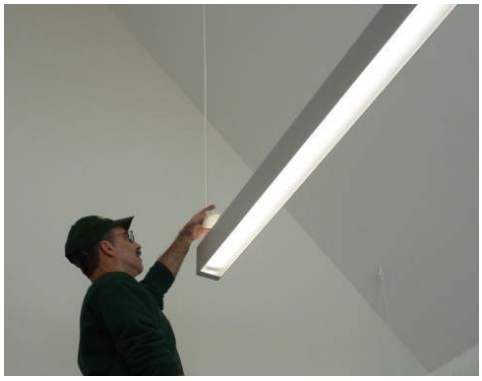

Figure 9. Facility staff adjusts a light fixture.

Facilities staff must be provided with information about the parameters of the electric lighting, control, and daylighting systems that have been designed, installed, and commissioned to ensure these systems provide circadian-effective lighting. They also must have enough knowledge to be able to assess how any changes they make to these parameters will affect the circadian effectiveness of the light provided by system. All of these factors should be well documented by the design team in a format that will allow facility staff to operate the lighting and daylighting systems effectively and educate further staff on the lighting and control system operation. It is not sufficient for the design team to simply pass along the warranty and operating instructions for each lighting system component. These must be accompanied by clear documentation of the design specifications along with operating and maintenance instructions.

Organizational Management

A sometimes-overlooked member of the integrated design team is a representative from the management of the organization that will occupy the building. The organization's management is not only crucial to provide input into the design, but also to understand design intent and how to support this intent among building occupants after the building is built. Once the organizational management has bought-in to the importance of circadian-effective lighting to the building occupants, they need to share information among every building occupant. Everyone must understand why the lighting is operating to provide circadian-effective lighting and the importance of this operation to the building's occupants well-being and sleep health.

Educational information should be shared with building occupants about circadian-effective lighting. There are several resources available online, including short videos, that can be used to help provide this information.

https://www.light-health.org/education/resources/ul-design-guideline-24480

Due to occupant turnover, information about circadian-effective lighting should also be shared and reinforced through periodic emails, building postings, signage, and other communication avenues to help ensure that building occupants understand how the operation of the lighting is designed to support their well-being and sleep health. Some information that should be shared with building occupants includes:

- Manual lighting control use – In many modern lighting systems, building occupants have access to manual controls, such as wall-mounted dimmers (Figure 10), that allow them to adjust the light levels in each space. Research has shown that once light levels are dimmed using these manual controls, they are often left at lower than specified levels and rarely changed again.[8] In situations where building occupants have manual control over light levels, it will be important for them to understand the benefits of higher light levels, at least during morning hours, to their sleep and overall health. Management could, for example, post a sign near dimming lighting controls encouraging occupants to turn up their lighting during the morning hours to help everyone sleep better at night. This could also be reinforced through periodic emails, in newsletters, or by other means of communication.

Figure 10. A manual lighting control in an office allows workers to adjust light levels.

- Automated control schedules – Building occupants can react negatively to environmental changes that are beyond their control, especially if they do not understand why changes are happening. For example, if light levels change throughout the day, this can become distracting, and even annoying to the occupants of a space. They may then ask for the system to be disabled, or the settings changed. If an automated control system is designed to ramp up light levels during the morning hours to provide circadian-effective lighting, and dimmed down following this period, it should be made clear to building occupants why these daily changes are happening and the benefits this provides to their health. Once this is explained, and periodically reinforced, it is much more likely that building occupants will accept changes to the lighting. Organizational management should also make clear who is allowed to make decisions about changes in the control settings, schedules, and other parameters to avoid changes being made that could negatively impact the circadian-effectiveness of the lighting.
- Daylight and window shades – Similar to manual lighting controls, research has shown that building occupants will often close window shades or blinds to reduce glare when the sun is directly visible and rarely open them again, even though there is no longer sunlight falling on the window.[9] Daylight is an excellent means of providing circadian-effective lighting and is typically considered as a contribution in the computational modeling performed by the lighting designer during the design process. If window shades or blinds are closed throughout the day, even when there is no direct glare from sunlight, this can significantly reduce the expected circadian-effective light levels in the space. Building occupants should be informed of the importance of daylight to the provision of circadian-effective lighting and should be encouraged to open blinds whenever possible (Figure 11). This could be reinforced by signage posted near windows, or management could even ask for employee volunteers who would be responsible for opening window shades or blinds in open office areas, when their closure is not needed.

Figure 11: A display in an office building explaining how building daylight supports circadian entrainment.

- Availability of a circadian-effective lighting oasis – As mentioned earlier, in buildings where it was not possible to provide circadian-effective lighting in all building spaces, the design team can consider creation of more

brightly lighted spaces in the building where employees could go to work, meet, take breaks, or interact with other staff. This strategy for providing circadian-effective lighting will only work if employees are aware of why these spaces exist, and how to best use them to promote their own sleep and overall health. Management could promote the use of these "circadian oases" in staff meetings, through signage, or by other means of communication. These communication methods should include education on how to best use these spaces, for example, at the same time each day to optimize the effectiveness of the circadian lighting. If outdoor areas are available for work or break period, management could also encourage employees to take advantage of these spaces when the weather allows.

CONCLUSIONS

There are several conclusions that can be drawn from an analysis of the IDP for circadian-effective lighting.

1. **Team Leadership and Communication is Key** – In a multidisciplinary, integrated design team it is important that there be an effective leader that will coordinate the work of the team from beginning to end and facilitate effective communication among team members and the client. Sufficient resources must be allotted in the project budget to cover the time required for this project coordination. In most building projects, this leader is the architect or a project manager working for the architect or directly for the client.
2. **Understanding and Buy-in from All Team Members is Crucial** – The very beginning of the project, through the life of the project it is crucial to the success of circadian-effective lighting that all members of the integrated design team have an understanding of what it is, and of its importance to the health of building occupants. It is also important that circadian-effective lighting is understood and valued by the client, building managers, and occupants.
3. **Core Integrated Design Team Members Most Impact Project Success –** In the design and implementation of circadian effective lighting, there are core team members in each phase of the project whose design work and decisions most impact the success of the design.
    a. **Design Phase** – In the design phase of the project, the core circadian-effective lighting team members are:
        i. **Architect** – The architect is primarily responsible for daylighting design, which can greatly impact the amount of circadian-effective light available for building occupants.
        ii. **Lighting Designer** – The lighting designer
            1. Oversees the process of designing circadian-effective lighting.
            2. Coordinates daylighting; ambient electric lighting; and localized, work-station-integrated or portable electrical lighting solutions.
            3. Conducts an analysis of the occupant needs in each space.
            4. Develops computational models of the lighting in the space, taking into account daylight, electric lighting contributions, and the spectral characteristics of the light, space and surface characteristics, furniture placement, and other factors.
            5. Works with the team to select furniture and finishes.
            6. Works with the electrical engineer to coordinate lighting control selection, placement, and configuration.
            7. Remains available throughout the project until commissioning.
        iii. **Interior Designer –** The interior designer is primarily responsible for furniture selection and placement, selection of colors and finishes for each space, and the selection of window covers.
    b. **Building Phase –** In the building phase of the project, the team member who most impacts the success of the circadian-effective lighting design is:

i. **Builder/contractor** – The builder or contractor must ensure that the lighting and daylighting decisions made by the core circadian-effective lighting design team members are implemented as designed. The builder must communicate with the team leader (e.g., architect or project manager) changes that can affect the circadian-effective lighting design, such as lighting, control, or glazing product substitutions, or changes to building configuration or interior finishes.
ii. **Commissioning Agent** – The commissioning agent is key to ensuring that all electric lighting and lighting control systems are set up and commissioned to provide the amount, duration, and timing of light specified.

c. Post Occupancy Phase – Once the building is occupied, the people that oversee the operation of building systems; the people who manage the employees; and the employees themselves must understand and value circadian-effective lighting, understand it's operation, and the how their actions impact its effectiveness.

i. **Facility Managers** – Must ensure that lighting and control system settings are maintained as designed to provide circadian effective lighting.
ii. **Operational Managers** – Must explain and reinforce the importance of circadian-effective lighting and how daylighting, ambient electric lighting, lighting controls, and localized lighting work together to provide a circadian-effective lighted environment for staff.
iii. **Employees** – Must understand how their interaction with window blinds, lighting controls, and other features of the lighting system will impact the circadian-effectiveness of the space for themselves and their colleagues.

4. **Key Design Decisions Affect the Circadian-Effectiveness of the Building** – It is not just the electric lighting that affects the circadian-effectiveness the lighted environment in the building. Other decisions are also important, including:
    a. **Daylighting** – Due to its broad spectrum and the sheer amount of daylight available from well-designed windows and skylights, daylight is an important contributor to an energy-efficient circadian-effective lighting design.
    b. **Ambient electric lighting** – The ambient lighting system provides a base layer of light that contributes significantly to circadian-effectiveness of a lighting design.
    c. **Local electric lighting** – Due to constraints in lighting distribution and the lighting power density limitations of energy-codes, it is often difficult to provide circadian-effective lighting from ceiling-mounted, ambient lighting fixtures alone. Therefore, it is always important to consider local, portable, or furniture integrated electric lighting solutions that move the light closer to the people who work in the space.
    d. **Lighting controls** – Circadian-effective lighting is not only about the amount of light, but also the time of day that the light is provided, and the duration it is provided. Lighting controls can ensure that circadian-effective light is provide at correct time, for the correct duration, and in the correct amount to be circadian-effective and energy-efficient.
    e. **Furniture and finishes** – The selection and placement of furniture and the colors and finishes of surfaces have an important influence on how much daylight and electric lighting reaches the eye of building occupants.

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REFERENCES

1. Ayodele Emmanuel Ikudayisi, Albert P.C. Chan, Amos Darko, Olumuyiwa Bayode Adegun, Integrated design process of green building projects: A review towards assessment metrics and conceptual framework, Journal of Building Engineering, Volume 50, 2022, 104180, ISSN 2352-7102, https://doi.org/10.1016/j.jobe.2022.104180.
2. Li Z, Tian M, Zhu X, Xie S, He X. A Review of Integrated Design Process for Building Climate Responsiveness. *Energies*. 2022; 15(19):7133. https://doi.org/10.3390/en15197133
3. Kamari, Aliakbar & Kirkegaard, Poul. (2020). Holistic Building Design: An integrated building design methodology based on systems thinking for reaching sustainability. 10.52842/conf.ecaade.2020.1.505.
4. Figueiro MG, Kalsher M, Steverson BC, Heerwagen J, Kampschroer K, and Rea MS (2018). Circadian-effective light and its impact on alertness in office workers. Lighting Research & Technology doi: 1177 /1477153517750006.
5. Figueiro MG and Rea MS (2016). Office lighting and personal light exposures in two seasons: Impact on sleep and mood. lighting Research and Technology 48(3): 352-64.
6. Figueiro MG, Steverson B, Heerwagen J, Kampschraer K, Hunter CM, Gonzales K, Plitnick B and Rea MS (2017). The impact of daytime light exposures on sleep and mood in office workers. Sleep Health 3(3): 204-215.
7. US General Services Administration (2024). P-100 Facilities Standards for the Public Buildings Service.
8. Maniccia D, Rutledge B, Rea MS, Morrow W. Occupant use of manual lighting controls in private offices. J. Illum. Eng. Soc. 1998;28(2):42-56.
9. Maniccia, D., B. Rutledge, M. Rea, and N. Narendran. 1998. A field study of lighting controls, Troy, NY: The Lighting Research Center.
10. Salazar, Maritza & Lant, Theresa. (2018). Facilitating Innovation in Interdisciplinary Teams: The Role of Leaders and Integrative Communication. Informing Science: The International Journal of an Emerging Transdiscipline. 21. 157-178. 10.28945/4011.
11. Heerwagen, Judith, and G. Orians. "The psychological aspects of windows and window design." In *Proceedings of 21st annual conference of the Environmental Design Research Association. Oklahoma City: EDRA*, pp. 269-280. 1990.