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Human-Centric and Integrative Lighting Asset Management in Public Libraries: Insights and Innovations on Its Strategy and Sustainable Development

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Abstract: In an era of rapidly advancing lighting technology and evolving public library roles, this study introduces a groundbreaking strategy for human-centric and integrative lighting asset management. Embracing both visual and non-visual effects, "integrative lighting" aims to enhance users' physiological and psychological well-being. Despite technological progress, notably with LEDs, current asset management often lags, relying on reactionary measures rather than proactive strategies. As public libraries transform into dynamic learning hubs, the significance of indoor lighting, impacting both physical health and holistic well-being, cannot be understated. Yet, many existing solutions are based on controlled lab tests, bypassing the diverse real-world needs of public libraries. Aiming to explore and develop human-centric and integrative lighting asset management strategies to optimize lighting environments in public libraries, this research offers a cohesive approach encompassing context identification, a management framework, and a maturity assessment model. Additionally, this study highlights the synergy between the role of the lighting asset manager, ISO 55000 principles, and these foundational strategies. This holistic approach not only reinvents lighting in public libraries but also aligns it with the broader Sustainable Development Goals (SDGs), advocating for light as a conduit of comprehensive human betterment. The current study is primarily qualitative in nature. While this study is based on public libraries in Nordic countries, the implications and findings can be of interest and value to a broader international audience.

Keywords: asset management; public libraries; human-centric lighting; integrative lighting; Sustainable Development Goals (SDGs)

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1. Introduction

"Human-centric lighting" [1,2], or a more widely accepted term "integrative lighting" [3,4], is specifically designed to have a beneficial physiological and/or psychological effect on humans and thus includes both visual (light intensity, flicker, glare, color temperature) and non-visual effects (biological and emotional benefits such as circadian rhythm, alertness, etc.) [4,5]. According to the strategic roadmap outlined by the Global Lighting Industry (GLA), the goal of achieving human-centric lighting is expected to be realized by 2040 [1].

The word "asset" refers to a system or individual equipment; the term "asset management" refers to the coordinated activity of an organization to realize value from its assets over the life cycle [6–8]. Lighting asset management aims to ensure the optimal performance, energy efficiency, and longevity of lighting assets while meeting the specific needs and requirements of the organization and efficiency. Human-centric and integrative lighting asset management aims to develop lighting asset management to promote

effective lighting and to help the users get the right light at the right time to support various activities.

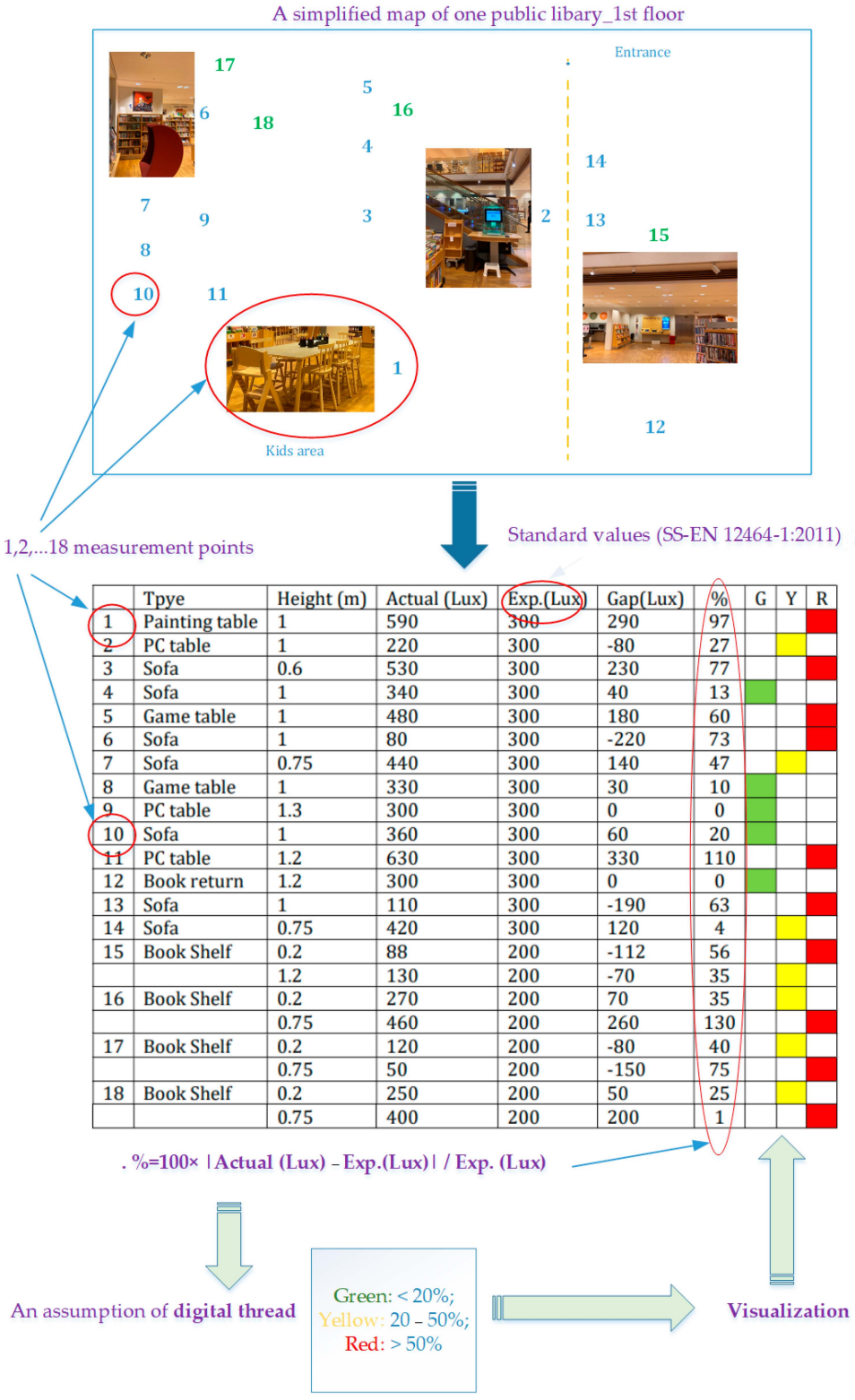
In recent years, lighting technology has seen significant disruptive technical advancements, particularly in light-emitting diodes (LEDs), resulting in improved performance and light quality [9]. These advancements bring us closer to achieving effective "human-centric" and "integrative" lighting. However, despite the progress in lighting technology, lighting asset management practices have not kept pace.

Initial findings from a preliminary study conducted in a single public library demonstrate that the health impact of human-centric and integrative lighting can be assessed by comparing real-time measurements against established standards and recommendations. Specifically, the disparity between these real-time measurements and the normative values offers a quantifiable basis for identifying potential health risks (refer to Figure 1). This methodology enables the setting of anomaly detection alarms and facilitates the diagnostic and prognostic processes, serving as a foundation for key performance indicators, monitoring, and forecasting. Nonetheless, this is just the beginning, and the current state of lighting asset management still primarily relies on corrective maintenance, i.e., "fix it only if it breaks". This strategy results in a lack of adequate monitoring or prediction of both visual and non-visual effects due to the limited level of asset management. Correspondingly, it struggles to achieve the ultimate goal of human-centric and integrative lighting.

Nowadays, the role of the public library is changing; instead of a warehouse for books, it is becoming a "social infrastructure" and is adapting to changing times [10,11]. Virtually all Nordic towns and cities have at least one public library, and people use them regularly. According to [12], Stockholm's public libraries had 81 million physical visits in 2019. While public libraries are known for their lively atmospheres, the importance of indoor lighting conditions is often underestimated. Especially after the building has been put into use, no matter if it is old or new, continuous monitoring and design review on both visual and non-visual lighting effects are very rare. Indoor lighting quality impacts not just physical health, such as vision issues, but also mental well-being, affecting mood and productivity for both users and staff. Human-centric and integrative lighting asset management in public libraries is urgently necessary in such a context.

Unlike traditional asset management, which often prioritizes the function, cost, and lifetime of assets, human-centric and integrative asset management places people at the center of decision-making processes and focuses on optimizing technical elements to enhance human health and well-being. An important challenge of lighting asset management in public libraries is how to manage human-centric and integrative lighting assets, given the increasing requirements and complexity involved when combining the visual and non-visual effects of light. Several innovative companies have embraced the concept of light as a service (LaaS), while researchers and institutes have focused on human-centric lighting, such as LightingEurope [13] and Lighting4People [14]. However, despite these efforts, the technical development of lighting technology is mostly based on test data conducted in controlled laboratory settings or limited scenarios in the lighting design stage, which fails to consider the variable operational contexts of real-world applications and the diverse needs of users with varying ages, heights, and activities in public libraries.

In summary, public libraries, increasingly seen as social infrastructures, face challenges in adapting lighting to diverse user needs. Traditional asset management often prioritizes functional, cost, and lifespan factors, while human-centric and integrative asset management emphasizes user well-being and health. Despite efforts by companies and researchers, there is a gap in the real-world application of advanced lighting technologies, which often do not consider the varied contexts and needs of library patrons. The urgent challenge that this study addresses is to help the users get the right light at the right time to support various activities in public libraries in a systematic and sustainable way, which is defined as human-centric and integrative lighting asset management in this study.



	Tpye	Height (m)	Actual (Lux)	Exp.(Lux)	Gap(Lux)	%	G	Y	R
1	Painting table	1	590	300	290	97			
2	PC table	1	220	300	-80	27			
3	Sofa	0.6	530	300	230	77			
4	Sofa	1	340	300	40	13			
5	Game table	1	480	300	180	60			
6	Sofa	1	80	300	-220	73			
7	Sofa	0.75	440	300	140	47			
8	Game table	1	330	300	30	10			
9	PC table	1.3	300	300	0	0			
10	Sofa	1	360	300	60	20			
11	PC table	1.2	630	300	330	110			
12	Book return	1.2	300	300	0	0			
13	Sofa	1	110	300	-190	63			
14	Sofa	0.75	420	300	120	4			
15	Book Shelf	0.2	88	200	-112	56			
		1.2	130	200	-70	35			
16	Book Shelf	0.2	270	200	70	35			
		0.75	460	200	260	130			
17	Book Shelf	0.2	120	200	-80	40			
		0.75	50	200	-150	75			
18	Book Shelf	0.2	250	200	50	25			
		0.75	400	200	200	1			

Figure 1. Preliminary results of the digital threads in one public library.

Following the introduction, the second section introduces the research methodology, focus, scope, hypothesis, and state-of-the-art review and emphasizes the imperative of human-centric and integrative lighting in public libraries which is accentuated through its synergy with the broader Sustainable Development Goals (SDGs). The third segment explores contexts specific to public libraries, followed by the unveiling of a structured framework for lighting asset management in the fourth section. Then, a maturity model is

introduced, aimed at providing benchmarks for effective lighting management. The sixth section provides insights into the role of the lighting asset manager and the principles of ISO 55000 [6–8] to illuminate a systematic and sustainable path for human-centric and integrative lighting asset management, with an accompanying matrix. The paper culminates in a conclusion, encapsulating the primary insights and offering recommendations for future endeavors in this domain.

2. Methodology, Hypothesis, Review, and SDG Alignment

Section 2 is pivotal in laying the foundational framework for our study, focusing on research methodology, the research focus and scope, the interplay of hypothesis formulation, a comprehensive review of relevant literature, and the alignment of our research objectives with the Sustainable Development Goals (SDGs). This section not only sets the stage for our investigative approach but also contextualizes our work within the broader scope of the existing knowledge and global sustainability ambitions.

2.1. Research Methodology, Focus, and Scope

Our study, centered on developing strategies and sustainable practices in human-centric and integrative lighting for public libraries, adopted a multifaceted research approach. While acknowledging the significance of empirical evaluation, the primary focus of this paper was on strategic development and sustainability in library lighting. This section summarizes the key components of our research methodology and the rationale behind the scope of this paper:

- State-of-the-Art Review: We conducted an exhaustive review of the existing literature to establish a solid theoretical foundation. This review spanned various dimensions of human-centric and integrative lighting, the complexities of lighting asset management, and current standards in library lighting.
- On-Site Observations: Detailed observations were made in 20 Swedish public libraries. These observations aimed to uncover both the evident and subtle challenges in the lighting environment, capturing the user perspective through participant observations. These findings were instrumental in shaping our understanding of the practical aspects of library lighting.
- Stakeholder Engagements: Our research included comprehensive interactions with diverse stakeholders, encompassing interviews and surveys with lighting professionals, library staff, and users. Over 100 responses were collected during these engagements, providing valuable insights into the real-world application of lighting strategies in libraries.

While these methods yielded extensive data and insights, the breadth and depth of our findings necessitated a focused approach in this paper. Consequently, we prioritized highlighting the strategic and sustainable aspects of human-centric and integrative lighting in public libraries. This focus aligns with our aim to contribute significantly to the discourse on sustainable lighting practices, particularly in the context of evolving library environments.

2.2. Connecting Hypotheses with the Study's Aim and Content

In this study, we formulate three key hypotheses to guide our research on human-centric and integrative lighting in public libraries. These hypotheses are designed to explore the impact of such lighting on user satisfaction and comfort, its alignment with global sustainability goals, and the effectiveness of staff training programs:

Hypothesis 1. *Implementing human-centric and integrative lighting in public libraries significantly improves user satisfaction and comfort compared to traditional lighting systems. This hypothesis is based on the premise that lighting that considers human needs and integrates well with the library environment will provide a more comfortable and satisfying experience for users than conventional lighting setups.*

Hypothesis 2. *The integration of human-centric lighting principles aligns with the Sustainable Development Goals (SDGs). We hypothesize that by focusing on human-centric aspects of lighting, libraries can contribute to several SDGs, including health and well-being, sustainable cities and communities, and responsible consumption and production.*

Hypothesis 3. *Training and awareness programs for library staff on human-centric and integrative lighting principles lead to more effective management and maintenance of lighting assets. This hypothesis suggests that equipping library staff with the necessary knowledge and skills will result in better management and upkeep of lighting systems, ensuring their optimal performance and alignment with human-centric principles.*

The aim of our study is to explore and develop human-centric and integrative lighting asset management strategies to optimize lighting environments in public libraries. This aim is intricately linked to our three formulated hypotheses, each addressing a crucial aspect of our comprehensive approach:

- Hypothesis 1 and Optimization of Lighting Environments: The first hypothesis directly supports our aim by proposing that such lighting strategies can optimize library environments. Our research methodology includes context identification and user feedback analysis to validate this hypothesis, thereby contributing to the optimization of lighting environments.
- Hypothesis 2 and Alignment with SDGs: The second hypothesis is explored through our study's component that evaluates how lighting strategies in libraries can contribute to global sustainability objectives. By demonstrating this alignment, the study reaffirms its aim of advocating light as a tool for comprehensive human betterment.
- Hypothesis 3 and Effective Management Strategies: The third hypothesis is directly related to our study's exploration of a management framework and the application of ISO 55000 principles. By examining the effectiveness of staff training and awareness programs, our study aims to reinforce the role of the lighting asset manager and the implementation of foundational strategies for optimal lighting management.

Collectively, these hypotheses guide our investigation into a cohesive approach that includes not just the technical aspects of lighting management but also the human and organizational factors. This holistic approach, as outlined in our study, seeks to reinvent lighting in public libraries, ensuring that it meets the needs of users and contributes positively to wider societal goals.

2.3. State-of-the-Art Review

The evolution of lighting in public libraries has spanned centuries, evolving from the reliance on natural daylight to the adoption of open-flamed lighting, gaslight technology, and ultimately, electric lighting. Today, the conversation about library lighting remains highly relevant and dynamic [15]. Initially regarded primarily for functional purposes and customer satisfaction, lighting has now transformed into a key element that significantly influences the health and well-being of users [9,14]. Thoughtfully designed and strategically placed lighting enhances user comfort and satisfaction. Conversely, deficiencies in lighting can deter library visits and adversely affect both staff and users. As modern libraries transition into vibrant learning centers, the importance of proper lighting becomes even more pronounced, underscoring its essential role in promoting human health and well-being.

A critical but often underemphasized aspect in lighting research is the ongoing evaluation of lighting conditions post-implementation. While most studies predominantly focus on the initial design phase of lighting [16,17], there has been a notable shift in recent research trends. These trends are exploring the integration of daylight in library building designs and the energy-efficient transition to LED lighting, with a focus on implementing strategies like parallel, perpendicular, indirect, or hybrid lighting schemes in public libraries [18,19]. Such approaches aim to maximize the infusion of natural light, leveraging strategic window placement and light redirection techniques to enhance the ambiance and

user experience within library spaces [20,21]. In addition to these design-oriented strategies, there has been a significant emphasis on efficiency-focused measures, particularly the adoption of LED lighting. This transition offers multiple benefits, including energy savings, an extended lifespan of lighting fixtures, and flexible, customizable lighting options. Furthermore, the integration of smart technologies, such as motion sensors, is being increasingly recognized for its role in optimizing energy use and reducing operational costs in library environments [22].

Current standards for human-centric and integrative lighting in public libraries, which include a range of aspects from lighting standards to BIM properties, are limited in several ways. Reliability standards for traditional light sources in libraries often assess only half the lamp's volume [23], which can lead to skewed performance assessments. Additionally, LED guidelines typically adhere to the "L70" benchmark [24], a standard that may not fully represent real-world scenarios, potentially causing misinterpretation and misapplication. The scope of these standards is also narrow, predominantly focusing on illumination levels and failing to cover the broader lighting needs and preferences of library users. Furthermore, the specified application contexts, such as bookshelves and reading areas, do not always reflect the diverse ways patrons interact with library spaces. There is also a noticeable research gap in the post-design phase of library lighting [25,26], especially in evaluating natural lighting, visual comfort, and energy usage patterns [27]. Most studies have concentrated on libraries at lower latitudes, leaving a significant gap in knowledge for libraries situated at higher latitudes over 55 degrees. This situation underscores the necessity for a more in-depth exploration into the effectiveness of lighting in libraries post-construction, advocating for continuous monitoring and evaluation of both visual and non-visual lighting impacts.

Based on the current knowledge, the urgent challenge that the study addresses is to help the users get the right light at the right time to support various activities in public libraries in a systematic and sustainable way. To meet the challenge, this study delves into insights and innovations in the identified contexts, management framework, and maturity assessment model because they form a sequential and interdependent strategy for effective human-centric and integrative lighting asset management. Aiming to explore and develop human-centric and integrative lighting asset management strategies to optimize lighting environments in public libraries, this study also lays the groundwork for systematic and sustainable advancement by providing insights into how a coordinated approach, informed by the role of the lighting asset manager and the principles of ISO 55000, integrates with the critical foundations of identified contexts, the devised framework, and the maturity assessment model.

2.4. Alignment with Sustainable Development Goals (SDGs)

Human-centric and integrative lighting asset management places people at the center of decision-making processes and focuses on optimizing technical elements to enhance human health and well-being. It aims to promote effective lighting and to help the users get the right light at the right time to support various activities, which plays a significant role in achieving Sustainable Development Goals (SDGs) [28] other than the lighting itself [29].

Table 1 presented here underscores the multifaceted contributions of strategic lighting management to achieving the SDGs, delineating both direct and indirect alignments. Direct alignments highlight the immediate benefits of lighting asset management, such as improved health and well-being (SDG 3), through the creation of visually comfortable environments, and bolstered quality education (SDG 4) via lighting that supports learning. Indirect alignments, on the other hand, encompass broader, ripple-effect benefits, such as the psychological advantages derived from circadian lighting designs, and the long-term energy savings from solar-powered solutions (SDG 7).

Table 1. Alignment with SDGs.

Aligned SDGs	Direct Alignment	Indirect Alignment
SDG 3: Good Health and Well-being	Proper visual environment for reading, studying, and computer work directly contributes to the well-being of library users, providing a conducive environment for reading and studying.	Circadian lighting design can indirectly promote psychological health of library users by supporting healthy sleep patterns and promoting alertness.
SDG 4: Quality Education	For after-school students, library usually serves as a self-learning center. Proper lighting is essential for creating an environment that supports reading and learning, especially in the afternoon.	In the library, the same environment needs to support flexible and adaptable activity purposes. Therefore, lighting design that accommodates various learning styles and activities indirectly contributes to the quality of education in public libraries.
SDG 7: Affordable and Clean Energy	Energy-efficient lighting systems and smart lighting control strategies in public libraries contribute directly to the goal of clean and affordable energy.	With the development of lighting technology, the use of solar tube (solar reflection through ductworks) is an indirect way to power lighting systems with solar energy, which indirectly supports the goal of clean energy.
SDG 9: Industry, Innovation, and Infrastructure	Moving from energy efficiency to lighting for health and well-being is a big shift that aligns with innovations that add extra value to society.	Exploring digitalization and intelligent lighting systems presents opportunities for innovative implications, contributing to industry and infrastructure development.
SDG 11: Sustainable Cities and Communities	Implementing sustainable lighting design in public libraries contributes directly to the goal of sustainable cities and communities.	Incorporating recycled materials or circular lighting design in lighting fixtures supports sustainability and aligns with the goal of sustainable communities.
SDG 12: Responsible Consumption and Production	Promoting energy-efficient lighting technologies aligns with responsible consumption and production.	
SDG 13: Climate Action	Implementing sustainable lighting design can directly contribute to reducing energy consumption and carbon emissions.	The use of renewable energy sources and energy-efficient lighting control strategies indirectly supports climate action.
SDG 17: Partnerships for the Goals	Digitalized collaboration between stakeholders to achieve sustainable lighting solutions aligns with the goal of partnerships for achieving the SDGs.	

This table serves not only as an articulation of these connections but also as a roadmap for stakeholders in the public library sector and beyond, demonstrating how targeted lighting strategies can significantly contribute to the ethos of the SDGs—spanning from responsible consumption (SDG 12) to fostering innovative partnerships for sustainability (SDG 17). Each entry outlines a dual impact—immediate operational improvements and long-term societal benefits—reinforcing the notion that effective lighting management extends well beyond the walls of the institutions it serves.

3. Context Identification in Public Library Settings

Contexts refer to the specific situations, settings, or environments in which the human-centric and integrative lighting asset management is applied, especially in public libraries. It concerns the unique challenges, user needs, and specific conditions that a library setting might present.

Recognizing these contexts is foundational. It is the first step because once we understand the specific situations or conditions we are working within, we can then build an effective management framework tailored to those contexts. This context information presents a comprehensive analysis of various factors (see Table 2) influencing human-centric and integrative lighting performance in public libraries, classified under several

categories, including (1) Context I: External Environmental Factors; (2) Context II: Interior Design Factors; (3) Context III: User Factors; (4) Context IV: Cost Factors; and (5) Context V: Regulation Factors.

Table 2. Context identification.

Identified Contexts (Factors)	Class [1]	
	Level I	**Level II**
External Environmental Factors	Geographic Location, Seasonal Changes, Circadian Rhythm, Occlusion Effects	Sunlight Intensity
		Temperature Variations
		Humidity
		Air Quality
Interior Design Factors	Building	Building Material Characteristics
		Daylight Interaction
	Furniture (Excluding Bookshelf)	Furniture Position
		Furniture Characteristics
	Bookshelf	Bookshelf Position
		Bookshelf Characteristics
	Fixed Lighting	Lighting Position
		Lighting Characteristics
		Human–Lighting Interactivity
	Adjustable Lighting	Lighting Characteristics
		Human–Lighting Interactivity
User Factors	Asset Manager	Guidance to Operators and Customers
	Operator	Operators' Behavior on Lighting
	Customer	Age
		Gender
		Height
		Activities
		Customer's Behavior
Cost Factors	Energy Consumption	
	Purchase	
	Installation	
	Operation	
	Maintenance (Inspection, Cleaning, Replacement, etc.)	
Regulation Factors	Asset Management Strategies/Regulations	
	Circular Economy/Sustainability/Society Impacts	
	Smart Buildings/Digitalization	
	Human-centric/Integrative Factors	

[1] The factors of level I and level II do not have one-to-one correspondence, and level II could be a compound effect of one or more factors in level I.

3.1. Context I: External Environmental Factors

This section discusses how external environmental factors (Context I) might influence human-centric and integrative lighting performance:

- Geographic Location: The amount and quality of natural light available in a certain location can greatly affect integrative lighting design. Locations closer to the equator receive more sunlight year-round than those closer to the poles, influencing the amount and type of artificial lighting needed.
- Seasonal Changes: Changes in seasons can affect the amount of natural daylight available, which can influence the timing and intensity of artificial lighting. For instance, during winter months, more artificial lighting may be needed.
- Circadian Rhythms: Light has a significant impact on our circadian rhythms, which are physical, mental, and behavioral changes following a daily cycle. Properly timed and tuned lighting can support healthy circadian rhythms, improving sleep and overall health. For example, cooler, brighter light in the morning can help increase alertness, while warmer, dimmer light in the evening can promote relaxation.
- Occlusion Effects: This refers to how buildings or other structures might block sunlight. If a building is in a location where other structures block sunlight, the interior may require more artificial lighting or innovative solutions to direct natural light indoors.

The above factors are level I in this context, and the ones below are level II and are influenced by contexts from level I:

- Sunlight Intensity: Sunlight intensity directly influences the amount and type of artificial lighting needed. On brighter days, less artificial lighting might be required, and the lighting system should be adaptable to these changes to save energy and maintain comfort.
- Temperature Variations: Extreme temperatures can affect the performance of some lighting technologies. For example, LED efficiency improves at lower temperatures, while high temperatures can reduce the lifespan of the light source.
- Humidity: Humidity can also impact the efficiency and lifespan of certain lighting systems. High humidity can cause some lights to fail earlier or may require more robust fixture designs.
- Air Quality: Poor air quality, such as high levels of dust or pollution, can scatter and absorb light, reducing its effectiveness. This may necessitate more or stronger lighting to achieve the same level of visibility. Also, poor air quality might cause faster degradation of lighting fixtures, necessitating more frequent maintenance or replacement.

3.2. Context II: Interior Design Factors

This section discusses how interior design factors (Context II) might influence human-centric and integrative lighting performance:

- Building:
    - Building Material Characteristics: The materials used in the construction and interior design of a building can significantly impact how light behaves in the space. Lighter materials reflect more light, which can help illuminate a space naturally and reduce the need for artificial light. The texture and color of the materials also influence the color and quality of reflected light.
    - Daylight Interaction: The amount and quality of natural light in a building depend on the design and orientation of the building, including the size, type, and placement of windows, skylights, and other openings. Optimizing this interaction can create a more pleasant and productive environment, reduce energy consumption, and help regulate occupants' circadian rhythms.
- Furniture (Excluding Bookshelf). In our study, we initially categorized furniture and bookshelves separately, although their influence on lighting considerations appears similar. Our rationale for this distinction lies in the different user interactions and durations associated with these elements. Typically, users spend more time using furniture, such as chairs or sofas, for activities like reading or learning, compared to the relatively shorter time spent at bookshelves searching for books. This difference in

usage significantly impacts the considerations for human-centric lighting solutions, as areas with prolonged user presence, like seating areas, have a more pronounced effect on human health and well-being:

- Furniture Position: The positioning of furniture can affect the distribution and reflection of light in the space. It can cause shadows or glare, depending on its location relative to light sources.
- Furniture Characteristics: The color, material, and texture of furniture can also influence how light is reflected or absorbed, affecting the overall illumination of the space.

- Bookshelf:
  - Bookshelf Position: The positioning of bookshelves can impact light distribution, potentially creating shadowy areas that require additional lighting.
  - Bookshelf Characteristics: The material and color of the bookshelves can affect how much light they reflect or absorb. Darker shelves may require more lighting for people to see the books clearly.
- Fixed Lighting:
  - Lighting Position: The position of fixed lighting affects the distribution of light, which can impact visibility and create different moods or effects.
  - Lighting Characteristics: The type of light bulbs used (LED, fluorescent, incandescent, etc.) and their color temperature and luminosity can significantly impact the ambiance of the space.
  - Human–Lighting Interactivity: This refers to how individuals can interact with and control the lighting system. Effective systems allow users to adjust lighting to their needs, enhancing comfort and productivity.
- Adjustable Lighting:
  - Lighting Characteristics: Adjustable lighting offers flexibility, allowing individuals to modify lighting conditions according to their needs or preferences, including brightness, direction, and color.
  - Human–Lighting Interactivity: As with fixed lighting, the ability for individuals to interact with and control adjustable lighting can significantly enhance the usability and comfort of a space, making it more human-centric.

3.3. Context III: User Factors

Human-centric and integrative lighting performance focuses on understanding and accommodating the needs and preferences of users. Clear communication and interaction between asset managers, operators, and customers are essential to achieve a lighting environment that promotes health, well-being, and productivity. This section discusses how user factors (Context III) might influence human-centric and integrative lighting performance:

- Asset Manager:
  - Guidance to Operators and Customers: The asset manager's role in providing clear instructions regarding the operation and benefits of the lighting system is crucial. This guidance can help operators use the lighting system more effectively and can help customers understand the intent behind the lighting design. For example, explaining the benefits of circadian lighting might encourage customers to appreciate and benefit from different lighting settings throughout the day.
- Operator:
  - Operators' Behavior on Lighting: How the operator uses and controls the lighting system can greatly affect the lighting conditions in a space. This includes turning lights on or off, adjusting brightness or color temperature, and managing natural light. If operators understand and value the concepts of

integrative/human-centric lighting, they are more likely to implement lighting changes that promote comfort, health, and productivity.

- Customer:
  - Age: Lighting needs can vary with age. A human-centric lighting design considers the diverse needs of different age groups. For instance, in areas of the library like the magazine and newspaper section, which are frequently used by older adults, implementing lighting with higher illuminance would be more appropriate. This approach not only caters to their specific visual requirements but also enhances their overall library experience.
  - Gender: Although it is not a primary factor, there are studies suggesting that gender may influence light perception and preferences, which should be considered in an integrative/human-centric approach. An existing gender difference in color preference for lighting could be a critical factor in enhancing certain areas of the library. For instance, considering that the staff at library counters are predominantly female, tailoring the lighting in these areas to align with research findings on color preferences among women could improve the working environment. This might involve adjusting the color temperature of the lighting to create a more comfortable and visually appealing workspace for the staff, thus acknowledging and addressing gender-specific preferences in lighting.
  - Height: This can influence how individuals perceive a space, including lighting. For example, higher-positioned lights might create shadows that shorter individuals find disruptive.
  - Activities: Different activities require different lighting conditions. For instance, reading requires focused, brighter light, while a social gathering might benefit from softer, more diffuse lighting.
  - Customer's Behavior: The way customers interact with the lighting system, their preferences, and their feedback can provide valuable information for improving the lighting design. If customers tend to adjust the lighting a certain way, or if they express comfort or discomfort with certain settings, these cues can guide adjustments to better meet their needs.

3.4. Context IV: Cost Factors

Cost factors can influence the cost of a human-centric and integrative lighting system, they also play a role in its performance, effectiveness, and user satisfaction. A well-designed system that considers all these aspects can provide significant benefits in terms of health, well-being, and productivity, which can justify the investment. This section discusses how cost factors (Context IV) might influence integrative lighting performance:

- Energy Consumption: One of the main costs associated with lighting is energy consumption. Efficient lighting technologies, such as LEDs, can reduce this cost significantly. However, the interplay between natural light and artificial light in integrative lighting design can also help optimize energy use. For instance, the use of daylight sensors can reduce the need for artificial light during the day, which can lower energy costs.
- Purchase: The initial purchase cost of lighting systems can vary significantly. More advanced, energy-efficient, and adjustable lighting systems may have a higher upfront cost, but they may offer greater benefits in terms of energy savings, lifespan, and user satisfaction in the long run.
- Installation: The complexity of the lighting system will influence the installation cost. Integrative lighting systems often involve a combination of different light sources, controls, and sensors, which may require professional installation. However, well-planned installations can provide long-term benefits in terms of energy efficiency, ease of use, and comfort.

- Operation: Operating costs include the regular cost of energy, as well as any costs associated with the control systems used to adjust the lighting. Smart controls can help optimize energy use and adapt the lighting to the needs and preferences of users, which can lead to increased satisfaction and productivity, potentially offsetting some of the operational costs.
- Maintenance: All lighting systems require some level of maintenance, including cleaning, bulb replacement, and potential repairs. While some lighting technologies, like LEDs, have longer lifespans and lower maintenance requirements, they still need to be considered in the overall cost. The design of an integrative lighting system should consider ease of maintenance to minimize disruption and cost.

3.5. Context IV: Regulation Factors

Regulation factors not only influence the cost and sustainability of lighting systems but also their ability to provide a comfortable, healthy, and productive environment for users. By considering these factors in the design and operation of lighting systems, we can move toward more human-centric, integrative, and sustainable built environments. These include the following:

- Asset Management Strategies/Regulations: Efficient asset management strategies and regulations can significantly improve the performance and lifespan of a lighting system. This includes regular maintenance schedules, inventory management, and compliance with safety regulations. Proper asset management ensures that the lighting system operates optimally, reducing the likelihood of malfunctions that can disrupt the human-centric lighting experience.
- Circular Economy/Sustainability/Societal Impacts: In a circular economy, products are designed to be used as long as possible, and at the end of their life, the components are reused or recycled. When it comes to lighting, this means choosing durable, energy-efficient lighting systems that can be easily repaired or upgraded, reducing waste and environmental impact. This aligns with sustainability principles and has positive societal impacts, such as reduced energy consumption and lower greenhouse gas emissions. It also encourages manufacturers to design lighting products that are easy to maintain and recycle, which can lead to more sustainable and user-friendly lighting solutions.
- Smart Buildings/Digitalization: With the advent of smart buildings, lighting systems can be controlled and monitored digitally, providing valuable data about their usage and performance. This can enable better energy management, help detect issues early, and allow for more personalized lighting settings, enhancing the human-centric approach. Furthermore, digitalization can enable the integration of lighting with other systems, such as heating or shading, for more holistic and efficient building management.
- Human-centric/Integrative Factors: Regulations that emphasize human-centric and integrative factors in lighting design can lead to better quality lighting environments. For example, regulations might stipulate the use of adjustable lighting that can mimic the natural progression of daylight, supporting the human circadian rhythm. They might also encourage the use of natural light and the creation of different lighting zones to cater to different tasks and preferences. These factors can significantly enhance the comfort, well-being, and productivity of users, which is the ultimate goal of human-centric lighting.

4. Framework Development for Effective Lighting Asset Management

This study develops a framework for human-centric and integrative lighting asset management, including various components and activities (Figure 2). This framework enables public libraries to adopt a unified and user-focused approach to oversee their lighting assets. By doing so, they ensure efficient upkeep, maintenance, and optimal performance, keeping user health and well-being in mind. The developed framework

resembles the structure of a house, complete with a roof, ceiling, walls, and floor. The framework components encompass setting clear objectives, developing a management system, planning, implementation, reviewing performance, enhancement, and integrating digital tools.

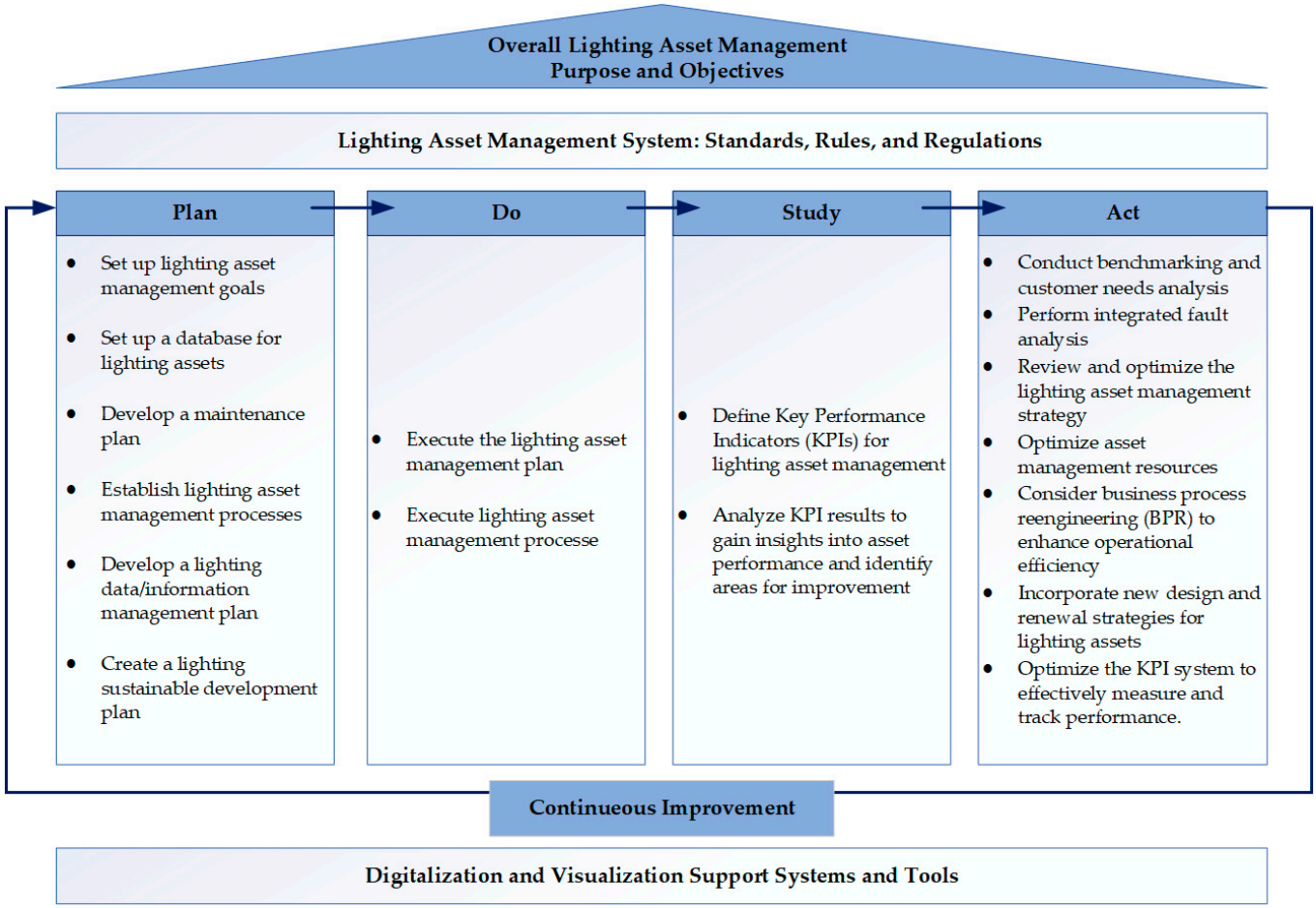


Figure 2. Lighting asset management house: the developed framework.

4.1. Overall Lighting Asset Management Purpose and Objectives

In the developed framework, the "roof" represents the overarching concept or main objective of the approach. In this case, the roof can be defined as the "Overall Lighting Asset Management Purpose and Objectives". The contents include the following:

1. Clearly define the overall purpose and objectives of lighting asset management: This involves establishing specific targets and outcomes that the lighting asset management process aims to achieve. The goals should be aligned with the organization's overall objectives.
2. Incorporate human-centric and integrative requirements into the overall purpose and objectives: This aspect highlights the importance of considering human factors, user experience, and integrative design principles when setting lighting asset management goals. Human-centric and integrative requirements emphasize the health and well-being of the people who interact with the lighting systems. Examples of human-centric and integrative requirements may include the following:
    - Providing lighting conditions that promote comfort and productivity.
    - Considering the visual needs and preferences of different user groups.
    - Designing lighting systems that contribute to the overall aesthetics and ambiance of the space.

- Incorporating controls and automation features that enhance user convenience and flexibility.
- Ensuring lighting systems support human circadian rhythms and promote well-being.
- Integrating lighting with other building systems to create a cohesive and harmonious environment.

By incorporating human-centric and integrative requirements into the overall lighting asset management purpose and objectives, public libraries can emphasize the importance of creating lighting solutions that not only fulfill functional requirements but also enhance the overall user experience and well-being. This approach acknowledges the significant impact that lighting has on occupants and seeks to optimize lighting assets to create environments that are comfortable, visually appealing, and supportive of human needs.

4.2. Lighting Asset Management System

In the developed framework, the "ceiling" represents the essential components that establish the system's foundation. In the settings of public libraries, the ceiling refers to the Lighting Asset Management System: Standards, Rules, and Regulations. An explanation of the content is as follows:

1. Establish the necessary standards, rules, and regulations for lighting asset management:
    - This involves defining a set of guidelines and criteria that govern the management of lighting assets in public libraries.
    - Standards may include technical specifications, recommended practices, and performance criteria specific to lighting systems in library environments.
    - Rules and regulations may encompass safety guidelines, electrical codes, and other compliance requirements relevant to lighting installations.
2. Ensure compliance with industry best practices and relevant regulations:
    - It is crucial to align lighting asset management practices with established industry best practices and regulations.
    - This may involve considering standards and guidelines set by organizations such as the Illuminating Engineering Society (IES), Building Owners and Managers Association (BOMA), or relevant local, regional, and national regulatory bodies.
    - Compliance with these standards helps ensure that lighting assets are managed efficiently, safely, and in line with recognized benchmarks.

In the case of public libraries, the establishment of standards, rules, and regulations for lighting asset management is important for several reasons:

- Safety: Lighting systems must adhere to safety standards to minimize the risk of electrical hazards and ensure the well-being of library patrons and staff.
- Performance: Defined standards enable the consistent performance of lighting systems, ensuring optimal illumination levels, color rendering, and energy efficiency.
- Consistency: Having established rules and regulations promotes consistency in lighting asset management practices across different library branches or locations.
- Compliance: Adhering to relevant regulations and codes helps libraries meet legal requirements and ensures they are operating within the prescribed guidelines.
- Accountability: Having a framework of standards and rules provides a basis for accountability in the management and maintenance of lighting assets.

By establishing and adhering to lighting asset management standards, rules, and regulations, public libraries can ensure that their lighting systems are safe, efficient, and compliant with industry best practices. This contributes to creating a conducive and user-friendly environment for library patrons while ensuring the longevity and optimal performance of lighting assets.

4.3. Plan

As one of the "walls" of the framework, the "Plan" represents a foundational element in the management of lighting assets. This wall encompasses various activities and processes that contribute to effective lighting asset management. The content includes the following:

1. Set up lighting asset management goals:
    - Identify and prioritize integrative/human-centric requirements for lighting assets specific to public libraries.
    - This involves understanding the unique needs and preferences of library users and aligning the lighting asset management goals accordingly.
    - Goals may include providing comfortable lighting for reading areas, optimizing energy efficiency, and enhancing the visual appeal of the library space. Examples of lighting asset management goals may include the following:
        - Enhancing the reliability and performance of lighting assets.
        - Minimizing downtime and disruptions caused by lighting asset failures.
        - Optimizing maintenance efforts and resource allocation.
        - Ensuring the safety and well-being of users in the lit environment.
        - Improving energy efficiency and sustainability of lighting systems.
        - Enhancing the visual comfort and quality of lighting for occupants.
2. Set up a database for lighting assets:
    - Establish a comprehensive database to store information related to lighting assets in public libraries.
    - Store asset information such as specifications, maintenance history, and condition data.
    - Classify lighting assets based on various criteria, such as location, type, or function.
    - Perform criticality analysis to prioritize maintenance efforts based on the assets' importance and impact on library operations.
3. Develop a maintenance plan:
    - Define the maintenance strategy for lighting assets to ensure their optimal performance and longevity.
    - Create a detailed maintenance plan that outlines schedules, tasks, and procedures for maintaining lighting assets.
    - Allocate necessary maintenance resources, such as personnel, tools, and materials, to execute the maintenance plan effectively.
4. Establish lighting asset management processes:
    - Develop maintenance processes that outline step-by-step procedures for executing maintenance tasks on lighting assets.
    - Implement fault management processes to address lighting asset failures promptly and effectively.
    - Establish spare-part management processes to ensure timely replacement of faulty components and minimize downtime.
5. Develop a lighting data/information management plan:
    - Determine the data requirements for effective lighting asset management.
    - Establish protocols for data collection, storage, and analysis, ensuring data integrity and accessibility.
    - Utilize data to monitor asset performance, identify maintenance needs, and make informed decisions.
6. Create a lighting sustainable development plan:
    - Incorporate sustainability considerations into lighting asset management practices for public libraries.

- Explore energy-efficient lighting solutions, such as LED technology or daylight harvesting, to reduce environmental impact.
- Consider sustainable procurement practices and disposal/recycling options for lighting assets.

By incorporating these elements into the "Plan" wall, public libraries can establish a robust framework for managing lighting assets in a human-centric and integrative manner. This helps ensure that lighting systems align with the specific needs of library users, enhance energy efficiency, and contribute to a sustainable and visually appealing library environment.

4.4. Do

As one of the "walls", the "Do" wall represents the execution phase of the lighting asset management plan. It focuses on carrying out the planned activities and processes to ensure the effective management of lighting assets. An explanation of the content is as follows:

1. Execute the lighting asset management plan:
   - Collect and verify data on lighting assets:
     - Regularly gather relevant data, including asset specifications, maintenance records, and condition data.
     - Verify the accuracy and completeness of the collected data to ensure their reliability for decision making.
   - Execute planned work orders for scheduled maintenance:
     - Implement the maintenance plan by performing scheduled maintenance tasks according to the predefined schedule.
     - Adhere to the established procedures and guidelines for carrying out maintenance activities.
   - Address unplanned work orders and emergencies promptly:
     - Respond to unplanned maintenance requests and emergencies related to lighting assets.
     - Prioritize and address these work orders promptly to minimize disruptions and ensure the safety of library users.
   - Manage fault occurrences and perform necessary repairs:
     - Detect and diagnose faults in lighting assets promptly.
     - Perform repairs or replacement of faulty components to restore the proper functioning of lighting systems.
   - Provide feedback on completed work orders and condition monitoring:
     - Document the completion of work orders, including details of tasks performed and any observations made.
     - Conduct condition monitoring to assess the health and performance of lighting assets and record the findings.
2. Execute lighting asset management processes:
   - Follow established maintenance, fault management, and spare-part management processes:
     - Adhere to the predefined processes and procedures for carrying out maintenance tasks, managing faults, and handling spare parts.
     - Ensure that the processes are consistently followed to maintain operational efficiency and standardize practices.
   - Ensure adherence to relevant procedures and guidelines:
     - Comply with applicable regulations, industry standards, and internal guidelines related to lighting asset management.

- Adhere to safety protocols to minimize risks associated with maintenance activities.

By executing the activities and processes outlined in the "Do" wall, public libraries can effectively implement their lighting asset management plan. This ensures the timely execution of scheduled maintenance, prompt response to unplanned work orders and emergencies, effective fault management, and adherence to established procedures. Through these actions, libraries can maintain the reliability, performance, and safety of their lighting assets, supporting a conducive and user-friendly environment for patrons.

4.5. Study

The "Study" wall focuses on the measurement and analysis of key performance indicators (KPIs) to evaluate the performance of lighting assets. The content includes the following:

1. Define key performance indicators (KPIs) for lighting asset management:
   - Establish a set of KPIs that reflect the critical aspects of lighting asset management in public libraries. In alignment with the goals, it is essential to incorporate human-centric and integrative requirements into the KPIs.
   - KPIs may include the following:
     - Asset availability and reliability: Measure the percentage of time that lighting assets are available and operational.
     - Data quality: Assess the accuracy, completeness, and reliability of data collected for lighting assets.
     - Lighting asset performance: Evaluate the performance of lighting assets, such as luminance levels, color rendering, and maintenance history.
     - Work execution and improvement: Monitor the execution of planned work orders, track improvement initiatives, and measure the effectiveness of maintenance efforts.
     - Gap analysis: Identify discrepancies between planned maintenance tasks and their actual execution to identify areas for improvement.
     - Maintenance resource utilization: Evaluate the effectiveness and efficiency of maintenance resources, including personnel, tools, and materials.
     - Energy efficiency of lighting assets: Measure the energy consumption of lighting assets and assess their efficiency.
     - Effectiveness of support systems: Evaluate the performance and impact of support systems, such as lighting controls or automation.
2. Analyze KPI results to gain insights into asset performance and identify areas for improvement:
   - Regularly analyze the data collected from the defined KPIs to assess the performance of lighting assets.
   - Identify trends, patterns, and areas that require attention or improvement.
   - Use the insights gained from the analysis to make informed decisions regarding maintenance strategies, resource allocation, and process improvements.
   - Adjust and refine lighting asset management practices based on the findings to optimize performance and enhance user experience.

By establishing and monitoring KPIs for lighting asset management in public libraries, the "Study" wall provides a structured approach to evaluate the effectiveness of asset management efforts. The analysis of KPI results enables data-driven decision making, helps identify areas for improvement, and supports continuous enhancement of lighting asset performance.

4.6. Act

The "Act" wall represents proactive actions and initiatives to improve lighting asset management. It focuses on continuous improvement and optimization. An explanation of the content is as follows:

1. Conduct benchmarking and customer needs analysis:
   - Engage with library users, work staff, and asset managers to understand their requirements and gather feedback on lighting asset management.
   - Evaluate the effectiveness of the existing asset management and information systems.
   - Consider energy efficiency and sustainability aspects to align with environmental goals and regulations.
2. Perform integrated fault analysis:
   - Analyze faults in lighting assets holistically to identify underlying systemic issues.
   - Look beyond individual failures and consider patterns or common root causes.
   - Develop strategies to address recurring or critical faults and prevent future occurrences.
3. Review and optimize the lighting asset management strategy:
   - Regularly review the effectiveness of the current asset management strategy in meeting the defined goals and objectives.
   - Identify areas for optimization and implement necessary changes to improve efficiency and performance.
   - Consider advancements in technology, industry best practices, and user feedback when refining the strategy.
4. Optimize asset management resources:
   - Provide training and skill development opportunities for maintenance staff to enhance their capabilities and expertise.
   - Optimize spare inventory management to minimize costs and ensure timely availability of necessary components.
5. Consider business process reengineering (BPR) to enhance operational efficiency:
   - Evaluate existing processes and identify opportunities for streamlining and optimizing workflows.
   - Redesign processes to eliminate bottlenecks, reduce redundancies, and improve overall efficiency.
6. Incorporate new design and renewal strategies for lighting assets:
   - Stay updated with advancements in lighting technology and design trends.
   - Integrate new lighting solutions or upgrade existing systems to enhance performance, energy efficiency, and user experience.
7. Optimize the KPI system to effectively measure and track performance:
   - Continuously evaluate and refine the KPIs used to measure the performance of lighting asset management.
   - Ensure that the KPIs align with the defined goals and provide meaningful insights for decision making.

By implementing the actions outlined in the "Act" wall, public libraries can drive continuous improvement in lighting asset management. These activities promote engagement with stakeholders, identify areas for enhancement, optimize resources, and ensure that the strategy remains aligned with evolving needs and industry standards. Ultimately, this contributes to better operational efficiency, improved user experience, and sustainable lighting asset management practices.

4.7. Digitalization and Visualization Support Systems and Tools

As the "floor", the focus is on digitalization and visualization support systems and tools. This component emphasizes the utilization of technology to enhance lighting asset management practices. An explanation of the content is as follows:

1. Leverage digital technologies and tools to enhance lighting asset management:
   - Embrace digitalization and utilize technology solutions to streamline and improve lighting asset management processes.
   - Adopt digital platforms, such as computerized maintenance management systems (CMMS), to centralize data, automate workflows, and facilitate efficient asset management.
2. Utilize visualization techniques for data analysis and decision making:
   - Implement visualization tools and techniques to analyze and present lighting asset data in a visual and intuitive format.
   - Utilize dashboards, graphs, and charts to visualize trends, performance metrics, and maintenance information.
   - This enables easier comprehension of complex data, facilitates data-driven decision making, and enhances communication among stakeholders.
3. Implement relevant software solutions and platforms for asset management:
   - Identify and implement software solutions specifically designed for lighting asset management.
   - Utilize software tools that offer features such as asset tracking, maintenance scheduling, data management, and performance analysis.
   - Choose platforms that align with the integrative/human-centric approach and support the specific needs of public libraries.

By incorporating digitalization and visualization support systems and tools as the "floor" of the lighting asset management house, public libraries can benefit in several ways:

- Improved efficiency: Digital technologies automate manual processes, reduce paperwork, and streamline workflows, resulting in increased efficiency and productivity in managing lighting assets.
- Enhanced data analysis: Visualization techniques enable easier interpretation and analysis of lighting asset data, facilitating better insights, trend identification, and informed decision making.
- Centralized information: Digital platforms centralize data, ensuring easy access to asset information, maintenance records, and condition data, enhancing collaboration and information sharing among stakeholders.
- Timely maintenance: Software solutions help schedule and track maintenance tasks, ensuring timely execution and reducing downtime or disruptions in library services.
- Cost optimization: Digital tools enable effective resource allocation, including optimizing maintenance staff schedules, spare-part-inventory management, and energy consumption analysis, resulting in cost savings.
- Improved communication: Visualization tools facilitate the clear and concise communication of lighting asset performance, maintenance needs, and progress reports to stakeholders, enhancing collaboration and transparency.

By leveraging digital technologies and visualization support systems, public libraries can enhance their lighting asset management practices, improve efficiency, and make data-driven decisions to create an optimal lighting environment for library patrons.

5. Maturity Assessment Model with an Accompanying Matrix

The maturity assessment model of human-centric and integrative lighting asset management is a tool used to assess the current effectiveness and efficiency of a library's lighting system and the processes involved in its management. The model provides an approach for evaluating the library's current position, helping identify areas for improvement, and

suggesting a clear path for progression. The typical stages in a maturity model are as follows (for more information, refer to Table 3 in Section 6):

- Initial: This is the starting point for the use of a new or undocumented repeat process.
- Repeatable: The process is at least repeatable, possibly with consistent results. Process discipline is unlikely to be rigorous, but where it exists, it may help ensure that existing processes are maintained during times of stress.
- Defined: The process is defined/confirmed as a standard business process and decomposed to levels 0, 1, and 2 (the latter being Work Instructions).
- Managed: The process is quantitatively managed in accordance with agreed-upon metrics.
- Optimizing: Process management includes deliberate process optimization/improvement.

Table 3. Maturity Assessment Matrix: Aligned with ISO 55000.

		Stage I. Initial	Stage II. Repeatable	Stage III. Defined	Stage IV. Managed	Stage V. Optimizing
Strategy	Overall	No formal strategy: decisions are ad hoc	Some consistency in decisions	Formal asset management	Strategy is implemented and monitored	Strategy is continuously refined
	ISO55000	No principles or guidelines outlined in ISO 55000	Early understanding of ISO 55000	Aligned with ISO 55000	Regular reviews against ISO 55000	
	Maintenance	Corrective	Preventive	Predictive	Proactive	
Process	Defined	No	Repeatable		Yes	
	Documented	No			Yes	
	Standardized	No			Yes	
	Monitored	No		Begin to monitor process performance	Regular monitoring and reporting of process performance	
	Controlled	No			Processes are consistently followed and controlled	
	Optimization	No				Proactive process optimization based on performance data; best practices are benchmarked and implemented
Data	Collected	Data collection is inconsistent or non-existent	Some data are collected	Data collection is part of the standard procedure		
	Analyzed	No	Analysis is minimal or absent	Analysis is part of the standard procedure	Comprehensive data analysis supports decision making; begin to use predictive analytics	Advanced analytics and AI are used for predictive and prescriptive insights
Decision Support		Decisions are based on individual experience or intuition	Some use of data in decision making	Defined criteria for decision making; regular use of data analysis	Decision making is data-driven; use of analytics for predictive insights	Decision making is proactive and strategic, supported by predictive and prescriptive analytics
Continuous Improvement		No formal improvement initiatives	Early efforts to improve efficiency and performance	Improvement objectives are defined and linked to strategy	Performance is regularly reviewed, and improvements are made	Continual, proactive improvement across cost, energy efficiency, and human-centric considerations
Digitalization		Little to no use of digital tools	Early adoption of digital tools	Digital tools are part of standard procedures	Digital tools are fully integrated	Advanced digital technologies (e.g., IoT, AI) are adopted
Visualization		Little to no use of visualization	Minimal use of visualization	Begin to use visualization for data analysis	Regular use of visualization for decision making	Visualization is used for advanced analytics and strategic decision making

In the case of a lighting asset management maturity model, libraries at the "Initial" stage might be managing their lighting systems in a very ad hoc manner with little systematic control or strategy. As they advance through the stages, they become more strategic and proactive, using data and feedback to manage their lighting systems more efficiently and effectively. At the "Optimizing" level, libraries would be continually assessing and improving their lighting management processes, utilizing advanced technology, and effectively balancing cost, energy efficiency, and user satisfaction.

The primary advantage of performing a maturity assessment is that it provides a pathway for continuous improvement, clearly indicating the next steps to take to advance from one level to the next.

5.1. Stage I: Initial

The "Initial" level in a maturity assessment can be understood as the phase where there is little to no structured management of the lighting assets in a public library. The actions taken at this level are often reactive rather than proactive and lack a strategic, coordinated approach. This is what is also referred to as "chaotic" and "ad hoc".

For instance, maintenance or replacements might occur only when a problem becomes apparent, such as a light bulb burning out. The decisions made at this stage are typically based on immediate needs and are usually made by individual staff members who take the initiative to address these needs, hence the term "individual heroics".

There might be no standardized processes in place for regular inspections, maintenance scheduling, or the tracking of the lighting system's performance. There may also be little understanding or application of industry best practices or the latest energy-efficient lighting technologies.

Data collection, if it occurs at all, is likely inconsistent and informal, making it difficult to monitor performance over time or make data-driven decisions. Budgeting for lighting maintenance and upgrades may be unpredictable, as costs are dealt with on a case-by-case basis.

Overall, at the "Initial" level, lighting asset management is largely unorganized and unpredictable, with no formal processes or strategies in place to guide actions. It is the starting point, from which libraries can begin to develop and improve their lighting asset management practices.

5.2. Stage II: Repeatable

The "Repeatable" level in a maturity assessment for lighting asset management refers to the stage where some standard processes or procedures have been established and are followed on a regular basis. The processes in place are repeatable, meaning they can be performed consistently over time. The consistency of results, however, may vary as the process discipline is still not rigorous.

For example, there might be a standard procedure for replacing a light bulb when it burns out or a routine schedule for cleaning and inspecting the lighting fixtures. These actions may be documented in some way, perhaps in a manual or checklist, which can be followed by any staff member. This is a step up from the "Initial" level, where actions are taken ad hoc and primarily rely on the individual actions of staff members.

However, at the "Repeatable" level, these processes are still likely to be basic and may not cover all necessary aspects of lighting asset management. They might not be thoroughly followed or enforced, particularly during times of stress, such as during peak library usage or if there are staff shortages.

While libraries at this level have begun to establish standard procedures for managing their lighting assets, they have not yet developed a comprehensive, strategic approach to lighting asset management. There may still be little use of data to inform decision making, and libraries may not yet be fully leveraging best practices or advanced technologies in their lighting management. Nevertheless, having repeatable processes in place is an important step toward improving the overall management of lighting assets.

5.3. Stage III: Defined

The "Defined" stage in a maturity assessment for lighting asset management is the point at which processes and procedures are not only established but also standardized across the organization. This level goes beyond merely having repeatable actions; it involves confirming and documenting these processes as standard operating procedures (SOPs) for

the business. The processes are further decomposed into various levels to provide clear, step-by-step instructions for different scenarios.

For instance, in lighting asset management, a defined process could involve the following:

- Level 0: An overarching process such as "Maintain Lighting System", which encompasses all activities related to maintaining the lighting assets in the library.
- Level 1: This might break down the Level 0 process into several major subprocesses, such as "Perform Regular Inspections", "Replace Burnt-out Bulbs", "Clean Lighting Fixtures", etc.
- Level 2: At this level, each Level 1 process is further decomposed into specific work instructions. For instance, "Perform Regular Inspections" might include detailed steps on how to inspect different types of light fixtures, what to look for during inspections, how often inspections should be performed, etc.

The "Defined" level reflects a significant advancement in maturity because the library has transitioned from ad hoc and repeatable activities to a fully structured and standardized approach. This approach ensures consistency in the management of lighting assets, allows for better planning and predictability, and helps reduce the reliance on individual staff members' knowledge and expertise. It also provides a solid foundation for continuous improvement, as well-defined processes are easier to measure, control, and enhance.

5.4. Stage IV: Managed

The "Managed" stage refers to the point at which processes and procedures are not only defined and standardized but also consistently monitored and controlled based on specific, agreed-upon metrics.

At this level, the organization uses quantitative methods to understand the effectiveness and efficiency of the processes involved in lighting asset management. This typically includes collecting and analyzing data on various process performance metrics, such as service downtime, frequency of lighting failures, time taken to perform maintenance tasks, energy efficiency, and costs associated with different processes.

For example, the organization might track the energy consumption of different types of lighting fixtures, the frequency and costs of bulb replacements, or the time required to resolve lighting issues. These metrics are usually defined in a way that aligns with the organization's goals and objectives, such as reducing energy consumption, minimizing costs, or improving lighting quality.

By quantitatively managing these processes, the organization can identify areas for improvement, make data-driven decisions, and ensure that the processes are delivering the expected results. This level of process maturity also enables the organization to better predict future performance based on historical data, which can greatly facilitate planning and resource allocation.

In summary, the "Managed" stage of maturity signifies a shift from qualitative to quantitative process management, where decisions are made based on data and metrics rather than intuition or guesswork.

5.5. Stage V: Optimizing

The "Optimizing" stage in a maturity assessment is the highest level of process maturity, representing an organization that is not only effectively managing its processes but also continuously seeking ways to improve and optimize them.

At this level, the organization is proactive in identifying opportunities for improvement, implementing changes, and measuring the impact of those changes. This involves regularly reviewing and analyzing process performance data, soliciting feedback from staff and stakeholders, benchmarking against industry standards, and staying abreast of new technologies, methods, or best practices in lighting asset management.

In terms of lighting asset management, optimization might include introducing more energy-efficient lighting systems, streamlining maintenance processes, integrat-

ing smart lighting controls, or leveraging predictive analytics to anticipate and prevent lighting failures.

It is important to note that optimization is an ongoing, iterative process. The organization does not just make one set of improvements and then stop; rather, it continually looks for new ways to enhance the efficiency, effectiveness, and value of its lighting asset management processes.

Furthermore, this stage often involves fostering a culture of continuous improvement within the organization, where everyone is encouraged to contribute ideas and take part in optimization efforts. This can greatly enhance the organization's adaptability and responsiveness to changing conditions or new challenges.

In summary, the "Optimizing" stage of maturity signifies an organization's commitment to continuous improvement and proactive, data-driven optimization of its lighting asset management processes.

6. Sustainable Development to Systematic and Sustainable Advancements

This study provides insights into how a coordinated approach, informed by the role of the lighting asset manager and the principles of ISO 55000, integrates with the critical foundations of identified contexts, the devised framework, and the maturity assessment model. An accompanying matrix helps with the benchmark and strategy decision making and thereby achieves systematic and sustainable development.

6.1. The Mandate of Lighting Asset Manager

Human-centric and integrative lighting asset management involves using a combination of natural and artificial lighting to create a sustainable and energy-efficient lighting system. In addition to reducing the library's energy consumption and environmental impact, human-centric and integrative lighting asset management can also improve the comfort and well-being of library customers and staff. Proper lighting can enhance reading conditions, reduce eye strain and fatigue, and create a welcoming and inviting atmosphere.

Asset managers in public libraries have an important role to play in implementing integrative lighting management. The role of an asset manager in public libraries for integrative lighting management (see Figure 3) involves overseeing the planning, implementation, and management of lighting assets in a way that maximizes their efficiency, effectiveness, and cost-effectiveness. Some specific tasks that an asset manager may perform in this role include the following:

1. Designing integrative lighting: The asset manager may work with lighting designers to develop an efficient lighting plan that meets the needs of the library and its patrons.
2. Conducting a lighting audit: An asset manager may conduct a lighting audit to assess the current lighting system in the library, identify any areas for improvement, and determine the energy consumption of the lighting system.
3. Developing a lighting management plan: Based on the findings of the lighting audit, the asset manager may develop a lighting management plan that includes strategies for reducing energy consumption, optimizing lighting levels, and minimizing maintenance costs.
4. Ensuring energy efficiency and reducing the environmental impact of the lighting system: The asset manager should ensure that the library's lighting system is as energy efficient as possible. This can be achieved using energy-efficient lighting fixtures, controls, and other technologies.
5. Ensuring maintenance implementation: The asset manager should ensure that the library's lighting system is maintained in a cost-effective manner. This can include regular inspections, preventative maintenance (cleaning, replacement of light bulbs and other components, etc.), and predictive maintenance (repairs as needed).
6. Implementing lighting upgrades: The asset manager may oversee the implementation of lighting upgrades, such as installing energy-efficient lighting fixtures (incl., LED), upgrading control systems (incl. implementing occupancy sensors to turn off

lights when areas are unoccupied), and incorporating daylight harvesting systems to maximize natural light.

7. Budgeting: The asset manager should work with the library's budget to ensure that adequate funds are available for lighting upgrades and maintenance.
8. Monitoring and analyzing lighting data: The asset manager may regularly monitor and analyze lighting data to ensure that the lighting system is performing as intended and functioning effectively and efficiently, as well as identify any areas for further improvement.
9. Training and educating staff: The asset manager may train and educate library staff on the proper use of the lighting system and best practices for lighting management.

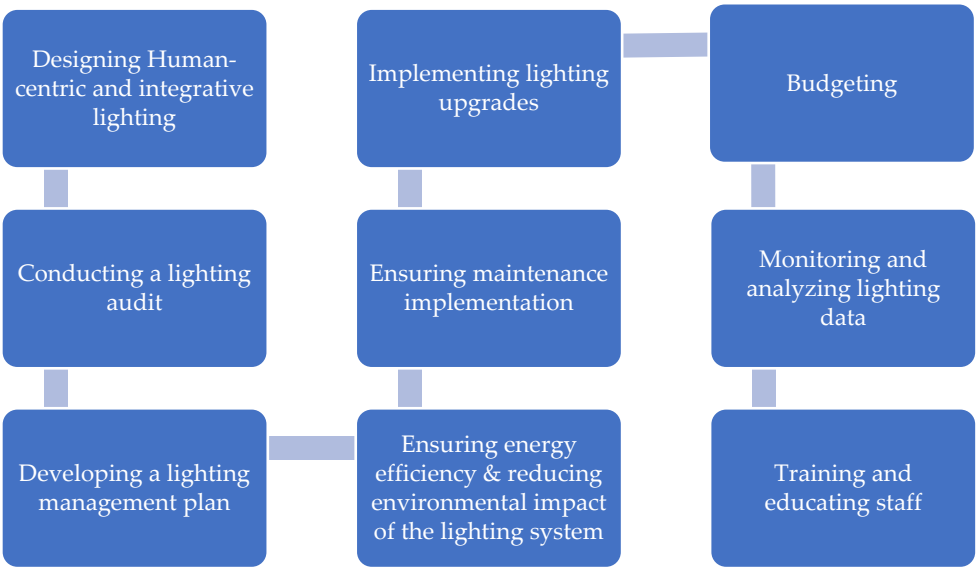


Figure 3. The role of lighting asset manager.

Overall, the role of an asset manager in public libraries for human-centric and integrative lighting management is to ensure that lighting assets are managed in a way that supports the library's goals while minimizing costs and reducing energy consumption. This includes ensuring the library's lighting system is well designed, energy-efficient, well maintained, and budgeted for, which can have significant benefits for both the library and its users. By optimizing lighting systems and implementing energy-efficient strategies, the asset manager can help the library reduce its environmental footprint and improve the quality of lighting for patrons and staff. An asset manager must work closely with other library staff and contractors to ensure that the library's lighting system is functioning effectively and efficiently.

6.2. Paving the Way to ISO 55000

To illuminate a systematic and sustainable path for human-centric and integrative lighting asset management, this study delves into the role of ISO 55000, examining its interplay with the foundational elements of the identified context, the formulated framework, and the maturity assessment model.

ISO 55000 is a standard developed by the International Organization for Standardization (ISO) that provides a framework for managing physical assets in an organization. This standard was first published in 2014 and is based on the asset management (AM) discipline [6–8]. It is a global standard that provides a framework for asset management in a systematic and structured way. It sets out the principles, requirements, and guidelines for an effective asset management system, which can be applied to any type of asset, including lighting assets in public libraries. The goal of ISO 55000 is to help organizations optimize the value they get from their assets by ensuring they are managed in a sustainable, cost-effective, and socially responsible manner.

Public libraries have unique lighting asset management needs as they typically have large spaces with different lighting requirements, such as reading areas, study spaces, and meeting rooms. In the case of lighting asset management in public libraries, ISO 55000 can play an important role in ensuring that the lighting assets are managed effectively. The standard provides guidance on the entire life cycle of an asset, from its design and installation through to its operation, maintenance, and disposal. This can help ensure that lighting assets are designed to meet the needs of the library and its users, installed correctly, maintained in good condition, and disposed of safely and responsibly when they are no longer needed.

Some specific ways in which ISO 55000 can benefit lighting asset management in public libraries include the following:

1. Establishing an asset management policy and ensuring that lighting assets are aligned with the library's strategic objectives: ISO 55000 requires the development of an asset management policy that defines the objectives, scope, and responsibilities for managing assets, including lighting assets in public libraries. By applying ISO 55000, the library can ensure that its lighting assets are aligned with its broader strategic objectives. This can help ensure that the lighting assets are designed and managed to support the library's goals, such as improving the user experience, reducing energy consumption, or increasing safety.
2. Conducting a risk assessment and providing guidance on risk management: A risk assessment helps identify potential risks and opportunities associated with lighting assets in public libraries. This includes identifying the risks of lighting failures, potential hazards, and the costs associated with maintenance and replacement. ISO 55000 provides guidance on how to identify and manage risks associated with asset management. In the case of lighting assets, this can help ensure that any safety risks associated with lighting (such as the risk of fire or electrical shock) are identified and mitigated.
3. Developing an asset management plan: Based on the risk assessment, an asset management plan is developed that outlines the strategies and actions required to manage lighting assets in public libraries. This includes maintenance schedules, repair and replacement plans, and investment strategies.
4. Implementing asset management activities and promoting cost-effective maintenance: The asset management plan is implemented by carrying out maintenance activities, monitoring asset performance, and continually reviewing and improving the management of lighting assets in public libraries. By following ISO 55000 guidelines for maintenance, the library can ensure that lighting assets are maintained in a cost-effective manner. This can include regular inspections, preventative maintenance, and predictive maintenance (repairs as needed).
5. Monitoring and review: ISO 55000 requires regular monitoring and review of asset management activities to ensure they remain effective and efficient. This includes reviewing asset performance, assessing the effectiveness of asset management strategies, and identifying opportunities for improvement.
6. Ensuring compliance with regulations and standards: ISO 55000 provides guidance on complying with relevant regulations and standards. In the case of lighting assets, this can include ensuring compliance with building codes, electrical safety regulations, and environmental standards.
7. Overall, by applying the principles, requirements, and guidelines of ISO 55000 to human-centric and integrative lighting asset management in public libraries, the library can ensure that its lighting assets are managed in a systematic and sustainable way and that they support the library's broader goals and objectives.

6.3. Maturity Model Aligned with ISO 55000

ISO 55000 is a series of international standards focusing on asset management. It provides guidelines and principles for establishing, implementing, maintaining, and improving an effective asset management system.

In the context of a maturity assessment aligned with ISO 55000 for lighting asset management, the stages might look the following:

- Initial: At this stage, organizations have an inconsistent or ad hoc approach to managing their lighting assets. There may be no standardized procedures, and any existing practices rely heavily on the individual knowledge and experience of personnel. The organization has not yet implemented the principles or guidelines outlined in ISO 55000.
- Repeatable: Organizations at this stage have established some repeatable procedures for managing lighting assets, though these may not be formally documented or consistently applied. The organization begins to introduce the concepts of ISO 55000, such as recognizing the value of their lighting assets and the importance of managing them effectively.
- Defined: The organization has a clear, documented process for managing lighting assets in alignment with ISO 55000. This includes setting asset management objectives, implementing an asset management plan, and establishing roles and responsibilities for asset management activities. The organization ensures that these processes are followed and understood by all relevant staff members.
- Managed: At this stage, the organization not only has defined processes but also uses key performance indicators and other metrics to monitor and manage the performance of its lighting assets. This is in line with ISO 55000's emphasis on performance assessment and continual improvement.
- Optimizing: The highest level of maturity. The organization is not just managing its lighting assets but also proactively seeking ways to improve its asset management system. This could involve benchmarking against industry best practices, using predictive analytics to optimize maintenance activities, or implementing advanced technologies like IoT for better asset monitoring and control. The organization continually reviews and adjusts its asset management system based on performance data, feedback, and changing business or regulatory requirements. This reflects ISO 55000's principle of continual improvement.

Each stage in this maturity model reflects increasing levels of adherence to ISO 55000's principles and guidelines, leading to more effective and efficient management of lighting assets.

6.4. Maturity Assessment Matrix

Following the developed maturity assessment structure, this section proposed a Maturity Assessment Matrix (see Table 3), which plays an important role in helping a public library evaluate and improve its processes, particularly in relation to lighting asset management in this context. Some specific ways the matrix can be beneficial are as follows:

- Performance Evaluation: It provides a structured framework for evaluating current performance. By comparing actual practices against the criteria in each stage of the matrix, an organization can understand its current maturity level.
- Identifying Areas for Improvement: The matrix helps highlight areas that need improvement. If an organization finds its practices align more with the "Initial" or "Repeatable" stages, it indicates that there are opportunities to enhance its processes and procedures.
- Guiding Progress: The matrix not only reveals where an organization currently stands but also points to what it can aim for. The detailed criteria provide a roadmap for advancing to higher maturity levels.

- Facilitating Communication and Understanding: The matrix can serve as a valuable communication tool. It helps everyone in the organization understand what good performance looks like and what steps need to be taken to achieve it.
- Supporting Strategic Decision Making: By providing a clear picture of current performance and potential improvements, the matrix supports more informed and strategic decision making.
- Continual Improvement: The nature of the matrix supports the philosophy of continual improvement. Organizations are encouraged to progress through the stages over time, constantly enhancing their processes and capabilities.

In conclusion, the Maturity Assessment Matrix is a comprehensive tool that helps a public library assess its current practices, identify areas of improvement, guide its progress, and support strategic decision making in the realm of human-centric and integrative lighting asset management.

7. Conclusions

Achieving effective human-centric lighting asset management in public libraries requires a multifaceted approach, deeply anchored in an understanding of specific contexts and scenarios. This paper underscored the significance of tailoring asset management strategies to distinct library environments. Our systematic exploration reveals a foundational triad: the nuanced intricacies of identified contexts, a robust management framework formulated to address these intricacies, and a maturity assessment model that evaluates the efficacy of the adopted strategies.

Aiming to explore and develop human-centric and integrative lighting asset management strategies to optimize lighting environments in public libraries, this research emphasizes that without appreciating the unique challenges and needs posed by different library settings, any management strategy remains incomplete and potentially ineffective. The management framework, therefore, stands as the nexus, drawing inspiration from these identified contexts to offer structured guidelines and processes. As organizations journey through the implementation of these guidelines, the maturity assessment model emerges as an indispensable compass, providing iterative feedback on areas of excellence and potential refinement.

The role of the asset manager, pivotal in this ecosystem, facilitates the seamless synergy of these components. As the linchpin, they ensure not only effective implementation but also a continual evolution of strategies based on real-time feedback and emerging best practices. Lastly, the inclusion of ISO 55000 elevates the entire discourse, aligning the local nuances of public library settings with globally recognized standards. Such adherence guarantees that human-centric lighting asset management not only caters to specific library needs but also resonates with international excellence benchmarks.

The current study is primarily qualitative in nature, and quantitative analysis is planned for future research within this project. While our study is based on public libraries in Nordic countries, the implications and findings can be of interest and value to a broader international audience.

In summary, the successful realization of human-centric and integrative lighting asset management necessitates a harmonized integration of context recognition, strategic planning, evaluation, skilled management, and global standards. This paper hopes to illuminate the path forward, ensuring that public libraries become luminous beacons of user-centricity and operational efficiency.

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References

1. Global Lighting Association. Strategic Roadmap of the Global Lighting Industry. 2015. Available online: https://globallightingassociation.org/images/files/GLA_Roadmap_usl_web.pdf (accessed on 2 November 2023).
2. Zhu, F.; Lin, Y.; Huang, W.; Lu, T.; Liu, Z.; Ji, X.; Kang, A.; Wang, H.; Chen, Z.; Wu, T. Multi-primary human-centric lighting based on the optical power ratio and the CCT super-smooth switching algorithms. *Build. Environ.* **2023**, *228*, 109880. [CrossRef]
3. ISO/CIE. *Light and Lighting—Integrative Lighting—Non-Visual Effects*; International Commission on Illumination: Vienna, Austria, 2022.
4. Jin, L.; Xue, P.; Zhang, L.; Wang, J.; Shi, J.; Liang, Q.; Cao, X.; Xu, N.; Liao, J. Visual and non-visual effects of integrated lighting based on spectral information. *Build. Environ.* **2023**, *242*, 110617. [CrossRef]
5. Madias, E.-N.D.; Christodoulou, K.; Androvitsaneas, V.P.; Skalkou, A.; Sotiropoulou, S.; Zervas, E.; Doulos, L.T. The effect of artificial lighting on both biophilic and human-centric design. *J. Build. Eng.* **2023**, *76*, 107293. [CrossRef]
6. *ISO 55000*; Asset Management—Overview, Principles and Terminology. ISO: Geneva, Switzerland, 2014.
7. *ISO 55000*; Asset Management—Management Systems—Requirements. ISO: Geneva, Switzerland, 2014.
8. *ISO 55000*; Asset Management—Management Systems—Guidelines for the Application of ISO 55001. ISO: Geneva, Switzerland, 2014.
9. European Commission. Lighting—Energy Labelling and Ecodesign Requirements Apply to This Product. 2019. Available online: https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products/lighting_en (accessed on 2 November 2023).
10. Veitch, J.A. Achieving Good Lighting Quality with integrative lighting: Opportunities and challenges. In Proceedings of the 11th Biennial Joint meeting, Gaithersburg, MD, USA, 3–4 October 2017.
11. Howard, J. The Complicated Role of the Modern Public Library. The National Endowment for the Humanities. 14 October 2023. Available online: https://www.neh.gov/article/complicated-role-modern-public-library (accessed on 2 November 2023).
12. Hilliard, W. *Stockholm's Public Libraries: Essential Public Spaces*; KTH Royal Institute of Technology: Stockholm, Sweden, 2021.
13. LightingEurope. Strategic Roadmap 2025 of the European Lighting Industry. 2016. Available online: https://www.lightingeurope.org/images/publications/ar/LE_AR2016.pdf (accessed on 2 November 2023).
14. Lighting For People. What Is Human Centric Lighting? 2015. Available online: http://lightingforpeople.eu/human-centric-lighting/ (accessed on 2 November 2023).
15. Metcalf, K.D. *Library Lighting*; The Association of Research Libraries: Washington, DC, USA, 1970.
16. Mostafavi, A.; Cruz-Garza, J.G.; Kalantari, S. Enhancing lighting design through the investigation of illuminance and correlated color Temperature's effects on brain activity: An EEG-VR approach. *J. Build. Eng.* **2023**, *75*, 18. [CrossRef]
17. Wymelenberg, K.V.D.; Inanici, M. A Critical Investigation of Common Lighting Design Metrics for Predicting Human Visual Comfort in Offices with Daylight. *LEUKOS J. Illum. Eng.* **2014**, *10*, 145–164. [CrossRef]
18. Edwards, B.W. Sustainability as a Driving Force in Contemporary Library Design. *Libr. Trends* **2011**, *60*, 190–214. [CrossRef]
19. Malman, D. Lighting for Libraries. Architectural Lighting Design, and Provided through the Libris Design Project, Supported by the U.S. Institute of Museum and Library Services under the Provisions of the Library Services and Technology Act, Administered in California by the State Library. 2005. Available online: https://ilovelibrariesblog.wordpress.com/2017/06/21/lighting-for-libraries/ (accessed on 2 November 2023).
20. Kilic, D.K.; Hasirci, D. Daylighting Concepts for University Libraries and Their Influences on Users' Satisfaction. *J. Acad. Librariansh.* **2011**, *37*, 471–479. [CrossRef]
21. Buhari, A.A.; Alibaba, H.Z. Analysis of Daylighting Quality in Institutional Libraries. *Int. J. Electr. Electron. Res.* **2019**, *7*, 6–20.
22. Bright Ideas for Public Libraries: Efficient Lighting for a Sustainable Future. Energy 5. 30 September 2023. Available online: https://energy5.com/bright-ideas-for-public-libraries-efficient-lighting-for-a-sustainable-future (accessed on 2 November 2023).
23. *IEC 60050-845*; International Electrotechnical Vocabulary (IEV)—Part 845: Lighting. IEC: London, UK, 2020.
24. LED Life for General Lighting: Definition of Life. ASSIST. 2005. Available online: https://www.lrc.rpi.edu/programs/solidstate/assist/pdf/ASSIST-LEDLife-revised2007.pdf (accessed on 2 November 2023).
25. Anugrah, M.P.; Munawaroh, A.S. Assessment of Natural Lighting and Visual Comfort of Library. In Proceedings of the 4th International Conference on Engineering and Technology Development, Bandar, Iran, 25–28 October 2017.
26. Kime, B.A. Comparative Analysis of Day lighting and Artificial Lighting in Library Building; Analyzing the Energy Usage of the Library. *Int. J. Adv. Res. Sci. Eng. Technol.* **2018**, *5*, 7665–7680.

27. Perera, N.; Swaris, N. Good Reading Light: Visual Comfort Perception and Daylight Integration in Library Spaces. In Proceedings of the 10th International Conference of Faculty of Architecture Research Unit (FARU), Colombo, Sri Lanka, 8 December 2017.
28. The 17 Sustainable Development Goals. United Nations. 2015. Available online: https://sdgs.un.org/about (accessed on 2 November 2023).
29. *How Lighting Contributes to the UN Sustainable Development Goals (SDGs)*; LightingEurope: Brussels, Belgium, 2022.