Dovetailing darkness and light for designing sustainable outdoor spaces

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Abstract

This paper aims to derive a design framework for dovetailing darkness and light while planning outdoor spaces using the concept of pragmatic utopia. Pragmatic utopia is a sustainable design movement characterized by an inclusive outlook towards ecologically, economically, and socially sustainable design. Ideological concepts of pragmatic utopian lighting design derived from literature are presented via their criteria for expanding sustainable lighting. Values of darkness derived from literature are presented via their spatial characteristics and temporal outlook. These ideological lighting concepts are then systematically matched with the darkness values to develop a dark-light design framework that can be used as a guidance tool for analysing and designing outdoor spaces with darkness and light. The applicability of this framework is tested by analysing three popular outdoor lighting projects that have addressed critical issues such as biodiversity protection, darkness preservation, heritage conservation, and social interaction as case studies. The objective is to use this framework for improving the ecological, economical, and socio-cultural fabric of outdoor spaces with carefully planned darkness and lighting.

Keywords: darkness, lighting, outdoor spaces, pragmatic utopia, sustainable design

1. Introduction

Lighting design processes involving outdoor spaces are generally rooted in functionalism as design plans start primarily with light. This paper argues for a dovetailed design process that is firmly rooted in aspects such as altruism towards the Earth and all its biodiversity [1–3], romanticism towards the night sky [4] and pragmatism towards the future of the lighting profession [5]. Drawing inspiration from the pragmatic utopian movement [6-7], the dovetailed process involves creation of design plans that start with both darkness and light. Pragmatic utopia is a term that was first coined by architect and bioregional planner Davidya Kasperzyk [8], and further developed by architect Bjarke Ingels [9] to describe a sustainable design movement that seeks a perfect world by tempering ecologically, economically and socially sustainable designs with reality. Kasperzyk [8] argues that people are fatigued by decaying safety and sociability, degradation of ecological quality, and urban sprawl in their neighbourhoods, as the status quo of sustainable design does not seem to be meeting public expectations. Ingels [9] further argues that while the traditional approach to sustainable design is an exclusive approach that settles for a compromising lowest common denominator, pragmatic utopia is an inclusive approach that ties together conflicting differences. Semantically, pragmatism and utopianism are two contradictory terms [7]: pragmatism advocates behaviour dictated by practical consequences rather than theory or dogma, while utopianism advocates for a perfect world that often conflicts with reality; pragmatic utopia therefore will be a marriage between the practical approach to reality, and the ideal of trying to create a sustainable life for future generations. The current

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approach to sustainable design is oriented around "three pillars" of sustainable design – ecology, economy and society. However pragmatic utopia, owing to its inclusive nature, has a much broader outlook towards ecologically, economically and socially sustainable designs.

The paper explores this inclusive nature of pragmatic utopia by regarding darkness as a resource that must be preserved and protected, thereby leading towards ecologically, economically and socially sustainable outdoor lighting. Under the pretext of ecologically sustainable outdoor lighting, the paper explores criteria beyond energy savings [10], to include health benefits for animals, humans and plants achieved from darkness. While a parochial human-centric focus [11] on the impact of light has overshadowed its effects on animals [12-13] and plants [14], mitigating light pollution and the intrusion of excessive stray light may lead to several benefits for animals, humans and plants. The benefits of darkness for animals include reduced dangers in terms of migration [15-16], orientation [17], and reproduction [18] as well as interactions with prey and predators [19]. The benefits of darkness for humans include reduced sleep disturbances thereby reducing chances of sleep and metabolic disorders [20-21], different types of cancers [21-22], obesity [23] and diabetes [24]; along with increased happiness, satisfaction, and wellbeing by creating more harmonious and symbiotic interactions with richly diverse ecosystems [25]. The benefits of darkness for plants include reduced dangers in terms of sexual expression [26] and reproductive output [27-28].

Under the pretext of economically sustainable outdoor lighting, the paper explores criteria beyond savings in investment and lifecycle costs of lighting systems [29], to include savings on healthcare, property and security achieved from darkness. Mitigating excessive brightness and glare may lead to several benefits for healthcare, property and security. The benefits of darkness for healthcare includes reduced chances of road accidents by shifting the light adaptation levels of vehicle drivers such that they can easily see details on the roadway or pedestrians crossing the road [30]. The benefits of providing only the minimum required level of lighting for property and security includes reduced chances of criminal and destructive activities like graffiti, theft or vandalism that actually thrive on bright nighttime lighting [31]. Under the pretext of socially sustainable outdoor lighting, the paper explores criteria beyond visual function and performance [32-33], to include people's experiences and perception of the dark and lighted spaces. Beautifying spaces by carefully designing the darkness and lighting of buildings and landscape may lead to benefits such as cultivation of feelings of safety [34], social involvement and vitality by attracting, directing and enchanting people within the urban context [35]. Additionally, selecting spaces to remain in natural darkness for either part or all of the night will bring back natural beauty and connection to the nighttime ecosystems and environments [25].

The paper aims to create a dovetailed design process of darkness and light, which allows room for darkness to set when lighting is no longer needed. Seven core ideologies of pragmatic utopia have been used to expand the criteria for sustainable lighting, and develop the concept of pragmatic utopian lighting design namely: discreetly integrate history, enterprisingly utilise resources, imaginatively explore regulations, methodically riposte nature, objectively fraternise societies, opportunistically mutate ideas, and sensitively acclimate paradoxes [6,7]. Nine values of darkness on the other hand have been articulated as prima facie obligations for incorporating into future design choices, policy-making, and innovations to nighttime lighting, namely: connection to nature, ecology, efficiency, happiness, healthiness, heritage and tradition, stellar visibility, sustainability, and wonder and beauty [36]. The paper builds upon these ideological concepts and values to develop an all-inclusive dark-light design framework with the goal to inform future design choices about critical issues such as biodiversity protection, darkness preservation, heritage conservation, and social interaction.

2. Method

The method for creating this dovetailed process of darkness and lighting design involves matching and merging the seven ideological concepts of pragmatic utopian lighting design with the nine darkness values based on their overall objectives. These concepts and values are then rewritten and framed into ideological concept-value questions, thereby formulating this all-inclusive pragmatic utopian dark-light design framework. Finally, three popular outdoor lighting projects that have critically addressed issues such as biodiversity protection, darkness preservation, heritage conservation, and social interaction are analysed as case studies to test the applicability of this framework.

3. Developing the Dark-Light Design Framework

The seven ideological concepts are matched with the nine darkness values based on their overall objectives as shown in Table 1. Some of these concept-value matches are more direct in nature considering their specific objectives, while some are more indirect in nature considering their generic objectives. The concept of discreetly integrating history can be directly matched to the value of preserving the cultural heritage of the night sky for future generations. The concept of enterprisingly utilise resources can be directly matched to the two values of saving money and energy as well as preserving non-renewable resources. The concept of methodically riposting nature can be directly matched to the value of preserving a connection to nature. The concept of objectively fraternising societies can be directly matched to the two values of promoting and fostering emotional and physiological wellbeing. The concept of sensitively acclimating paradoxes can be directly matched to the value of preserving and protecting biodiversity and species. The two concepts of imaginatively exploring regulations and opportunistically mutating ideas can be indirectly matched to all the nine darkness values. Similarly, the two values of preserving the visibility and aesthetic appeal of stellar night sky are values that can be generically included in the previous five concept-value matches.

Table 1: Matching Ideological Concepts of Pragmatic Utopian Lighting Design with Values of Darkness

Matching Characteristics	Seven Ideological Concepts of Pragmatic Utopian Lighting Design		Nine Values and Prima Facie Obligations of Darkness	
Direct + Specific	1.	Discreetly integrate history	I.	Heritage and tradition – Preserving the cultural heritage of the night sky for future generations
	2.	Enterprisingly utilise resources	II.	Efficiency – The responsible use of lighting where and when needed; money-saving
			III.	Sustainability – The responsible use of lighting where and when needed; energy-saving and preserving non-renewable resources
	3.	Methodically riposte nature	IV.	Connection to nature – Preserving a connection to the more-than-human world
	4.	Objectively fraternise societies	V.	Happiness – Promoting and fostering happiness; emotional wellbeing
			VI.	Healthiness – Promoting and fostering human health; physiological wellbeing
	5.	Sensitively acclimate paradoxes	VII.	Ecology – The protection and preservation of species and biodiversity; habitat conservation efforts
Indirect + Generic	6.	Imaginatively explore regulations	VIII.	Stellar visibility – Preserving conditions for access to the firmament
	7.	Opportunistically mutate ideas	IX.	Wonder and beauty – Preserving the aesthetic appeal of the natural night sky

The five direct and specific concept-value matches are rewritten as the following: Discreetly integrating history to preserve the cultural heritage and tradition of the night sky for future generations; Enterprisingly utilising resources to ensure the efficient and sustainable use of lighting for saving energy and money as well as preserving non-renewable resources; Methodically riposting nature to preserve a direct connection to nature beyond the human world; Objectively fraternizing societies to promote happiness and healthiness for human emotional and physiological well-being; Sensitively acclimating paradoxes to protect and preserve biodiversity of different species. On the other hand, the indirect and generic concept-value matches are rewritten as the following: Imaginatively exploring regulations and opportunistically mutating ideas to preserve the beauty and visibility of the stellar night sky. Having rewritten the concept-value matches, it is now important to include measurement indices to either qualitatively or quantitatively ascertain how a project meets each of these matches. The six

rewritten concept-value matches along with their respective measurement indices are listed as the defining questions of the pragmatic utopian dark-light design framework as shown in

Table 2.

Table 2: Dark-Light Design Framework for Dovetailing Darkness and Lighting

	Project/Location	Measurement Index
1.	Does the project discreetly integrate history to preserve the cultural heritage and tradition of the night sky for future generations?	Minimal upward light
2.	Does the project enterprisingly utilise resources to ensure the efficient and sustainable use of lighting for saving energy and money as well as preserving non-renewable resources?	Minimal use of resources for lighting
3.	Does the project methodically riposte nature to preserve a direct connection to nature beyond the human world?	Maximal connection to nature using light
4.	Does the project objectively fraternize societies to promote happiness and healthiness for human emotional and physiological wellbeing?	Maximal comfort for humans
5.	Does the project sensitively acclimate paradoxes to protect and preserve the biodiversity of different species?	Minimal disturbance to nature from light
6.	Does the project imaginatively explore regulations and opportunistically mutate ideas to preserve the beauty and visibility of the stellar night sky?	Minimal upward light

4. Applying the Dark-Light Design Framework

Three outdoor lighting projects exemplifying characteristics such as biodiversity protection, darkness preservation, heritage conservation, and social interaction are used as case studies for testing the pragmatic utopian design framework for darkness and light. The idea is to examine each project on its individual merits and explore their inclusive nature by adding any missing ideological values using the framework. The exemplified projects should neither be considered a comprehensive list of projects whose design vision is in-line with this Nuevo-modern movement, nor should the projects themselves be assumed to identify with this movement. These projects have only influenced this paper with characteristics, which might be useful in achieving the overall aim of carefully designing darkness and light.

4.1 Case Study # 1 – Sustainable Housing, Zuidhoek-Nieuwkoop/The Netherlands

The sustainable housing project outdoor lighting system for the town of Zuidhoek-Nieuwkoop, the Netherlands has been projected as a uniquely developed 'bat-friendly' project [37,38]. The town and its surrounding area is part of a network of nature protection areas across Europe comprising breeding and nesting sites especially for some rare and threatened bat species. Outdoor lighting at night can dramatically change the behaviours of light avoiding nocturnal species adapted to a life in darkness such as bats. Bats may have to use suboptimal routes with reduced cover for reaching foraging areas so as to avoid outdoor lighting: thereby increasing their vulnerability to aerial predators and energetic losses due to increased exposure to wind and rain, with consequential negative effects on reproduction rates and fitness [39]. A study [40] reveals that in order to limit the negative impact of outdoor lighting on some light-shy species of bats, white and green light should be avoided in or close to their natural habitat; but red light, which is perceived by bats as darkness, may be used if illumination is needed. While a study [41] reveals almost no effect of light colour on a particular bat species, another study [42] highlights that in contrast with the attention paid to the impacts on individual species, there remains rather limited understanding of how whole ecological communities respond to outdoor lighting. Therefore, the intent should be to design the outdoor light spectrum to reduce the impact upon the natural functioning of as many life forms as possible; and in the case of Zuidhoek-Nieuwkoop an additional species that could be taken into consideration for its outdoor lighting system is fireflies.

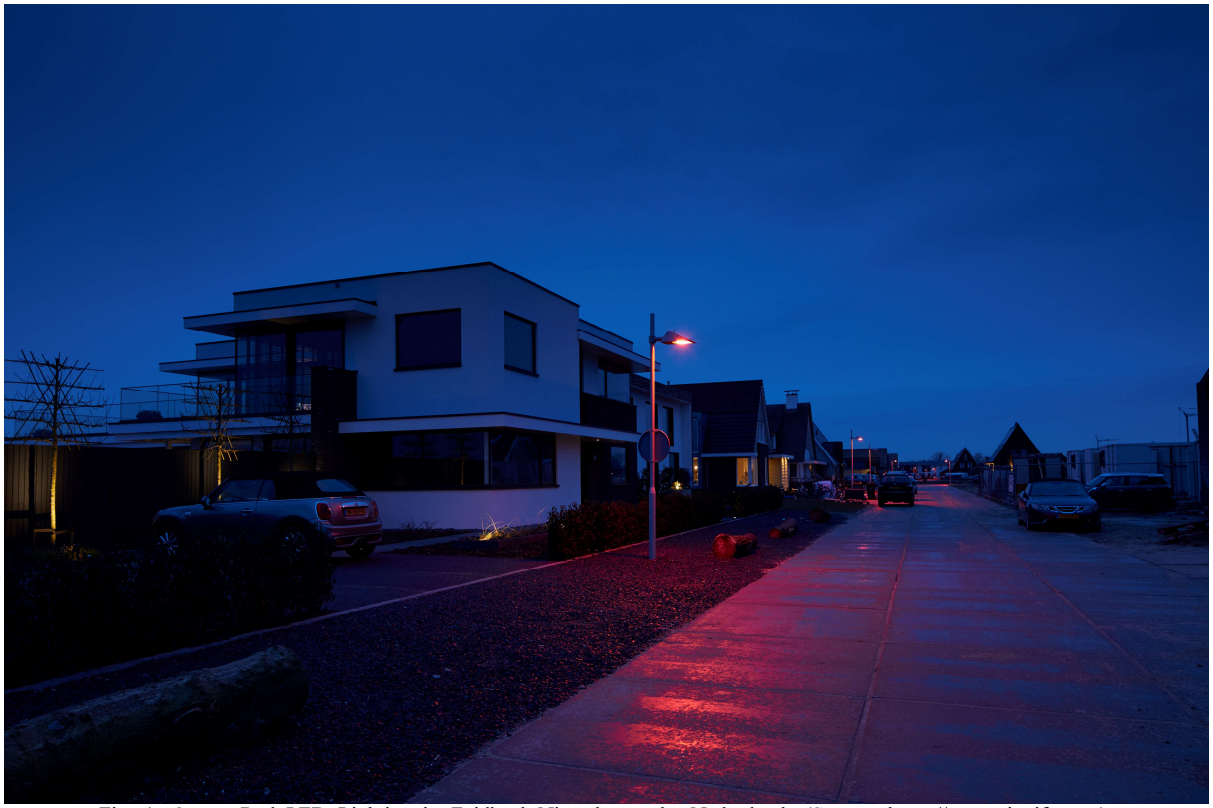

Fig. 1: Orange-Red LED Lighting in Zuidhoek-Nieuwkoop, the Netherlands (Source: https://www.signify.com).

Table 3: Dark-Light Analysis of Case Study # 1

	Sustainable Housing, Zuidhoek-Nieuwkoop/The Netherlands	Measurement Index
1.	Does the project discreetly integrate history to preserve the cultural heritage and tradition of the night sky for future generations?	Yes (Minimal upward light from the lighting system)
2.	Does the project enterprisingly utilise resources to ensure the efficient and sustainable use of lighting for saving energy and money as well as preserving non-renewable resources?	Yes (Minimal use of energy from the lighting system)
3.	Does the project methodically riposte nature to preserve a direct connection to nature beyond the human world?	No (No direct connection to nature)
4.	Does the project objectively fraternize societies to promote happiness and healthiness for human emotional and physiological wellbeing?	Yes (Maximal human comfort from the lighting system)
5.	Does the project sensitively acclimate paradoxes to protect and preserve the biodiversity of different species?	Yes (Minimal disturbance to bats and fireflies from the light spectrum)
6.	Does the project imaginatively explore regulations and opportunistically mutate ideas to preserve the beauty and visibility of the stellar night sky?	Yes (Minimal upward light from the lighting system)

The analysis of the housing project in Zuidhoek-Nieuwkoop with the dark-light design framework is presented in Table 3. The highly energy efficient outdoor lighting system of Zuidhoek-Nieuwkoop has incorporated an LED light source producing special light recipe of orange-red spectrums (≈630nm range), which seemingly causes minimal disturbance to both bats and fireflies as shown in Fig. 1. Fireflies exhibit flashes of light produced within their abdomens from the enzyme luciferase, enabling communication about reproduction and many other life habits, which can be reduced by up to 50% in the presence of outdoor light at night [43]. A study [44] suggests the use of long wavelength ambient light (≥597 nm) in place of broad-spectrum white light to augment firefly

conservation efforts, as it does not affect the signal morphology and courtship of certain species of fireflies, likely because these species cannot perceive these wavelengths. A potentially firefly-friendly lighting could lead to one of the most beautiful and natural lighting installations as photographed by Tsuneaki Hiramatsu [45]. Additionally, this outdoor lighting system includes a collective of parking area, pathway, and street lighting luminaires that provides sufficient illumination for easy navigation of roads and pavements by humans.

4.2 Case Study # 2 – Queen Elizabeth Olympic Park, London/UK

The immersive installation at the Queen Elizabeth Olympic Park in London, UK has been projected as a legacy project that effectively uses darkness as well as light [46,47]. As part of a wider lighting master plan for the London 2012 Summer Olympics Park and former athlete's village, an open concourse encompassing parklands, waterways and play spaces was transformed into a long promenade (≈500m) for user engagement. Models and theories from behavioural sciences, environmental psychology and social studies discussing the collective needs of people ensure that focus on the reduced energy use is not detrimental to human experiences of outdoor spaces after dark. A study [48] reports that people demand for a deeper experience of energy savings, safety perception and social participation with the meaningful use of colourfully layered and interactive lighting effects. Along with other art forms, lighting can be an enabler for creating a closely-knit community [49].

Fig. 2: LED catenary system in Queen Elizabeth Olympic Park, London/UK (Photographer: James Newton; Source: https://www.smlightarchitecture.com)

The analysis of Queen Elizabeth Olympic Park in London with the dark-light design framework is presented in Table 4. A uniquely developed catenary system of 56 galvanized and perforated metal spheres (≈1m dia.) suspended over the promenade provides a dappled effect reminiscent of natural light filtering through a tree canopy as shown in Fig. 2. A custom-designed LED light module was developed to provide the required light distribution and work with the catenary system. Illuminated tree canopies on either side frames this bold and playful lighting element. The spheres are connected to a site-wide lighting control system that dims promenade lighting levels between hours of prime usage to later at night. A number of open spaces are allowed to remain

dark wherever possible so as to provide areas of calm by not over-lighting the park and create a natural balance in light levels. The lighting supports the joyful character of the park design and ensures that users feel safe and secure, while reusing existing resources such as the lighting equipment used during the Olympic games.

Table 4: Dark-Light Analysis of Case Study # 2

	Queen Elizabeth Olympic Park, London/the UK	Measurement Index
1.	Does the project discreetly integrate history to preserve the cultural heritage and tradition of the night sky for future generations?	No (Upward light from globes and tree canopies causes light pollution)
2.	Does the project enterprisingly utilise resources to ensure the efficient and sustainable use of lighting for saving energy and money as well as preserving non-renewable resources?	Yes (Minimal use of energy and resources from the lighting system)
3.	Does the project methodically riposte nature to preserve a direct connection to nature beyond the human world?	Yes (Maximal connection to nature from the dappled natural light effect)
4.	Does the project objectively fraternize societies to promote happiness and healthiness for human emotional and physiological wellbeing?	Yes (Maximal human comfort from the lighting system)
5.	Does the project sensitively acclimate paradoxes to protect and preserve the biodiversity of different species?	No (Upward lighting of tree canopies may disturb certain species)
6.	Does the project imaginatively explore regulations and opportunistically mutate ideas to preserve the beauty and visibility of the stellar night sky?	No (Upward light from globes and tree canopies causes light pollution)

4.3 Case Study # 3 – High Line, New York/USA

The innovative lighting system for High Line in New York, USA enhances the visibility of the evening cityscape and the night sky [50,51]. The High Line is an elevated public park built on a historic freight rail line on the West Side of Manhattan. The neighbourhood residents and City of New York saved it from demolition, which enabled its transformation into a hybrid public space where visitors can experience art, design and nature. The emerging trend in the ever-evolving realm of outdoor lighting is to perceive darkness as a resource that is valuable to all living beings while being available for free from an energy standpoint. A study [52] allows for the classification of darkness as a resource owing to its dependence for the successful growth and reproductive behaviours of all living beings, in the same way space, temperature and time can be classified as resources. When darkness is perceived as a resource, the expense on other resources such as advanced lighting controls technologies are not only justified in energy savings, but also in the gain of a darkened environment.

The analysis of High Line in New York with the dark-light design framework is presented in Table 5. The energy-efficient LED lighting system installed at low heights eliminates overhead glare thereby enabling unique and spectacular night views of the city as shown in Fig. 3. The lighting design creates an environment that feels safe when darkness falls while enabling visitors to take in views of the night sky. The pathways are illuminated with low-height luminaires subtly integrated within benches, handrails, and accentuated areas of vegetation for inviting visitors to comfortably enjoy nature within the city. The staccato rhythm of dark and light provides a textural dynamic to the pathway that compels visitors to make forward progress as they walk. Keeping sensory observation central, the design introduces darkness and lighting on the architecture and landscape while enhancing the experience with a sense of fascination and mystery. Memories from history are also part of the experience where linear fluorescent lamps in some of the interior spaces create a rhythm of light and form reminiscent of the industrial spaces that were serviced by the old freight line. All of the luminaires are applied with discretion, creating a subtle glow that defers to the magnificence of the city and the rough beauty of this industrial landmark.

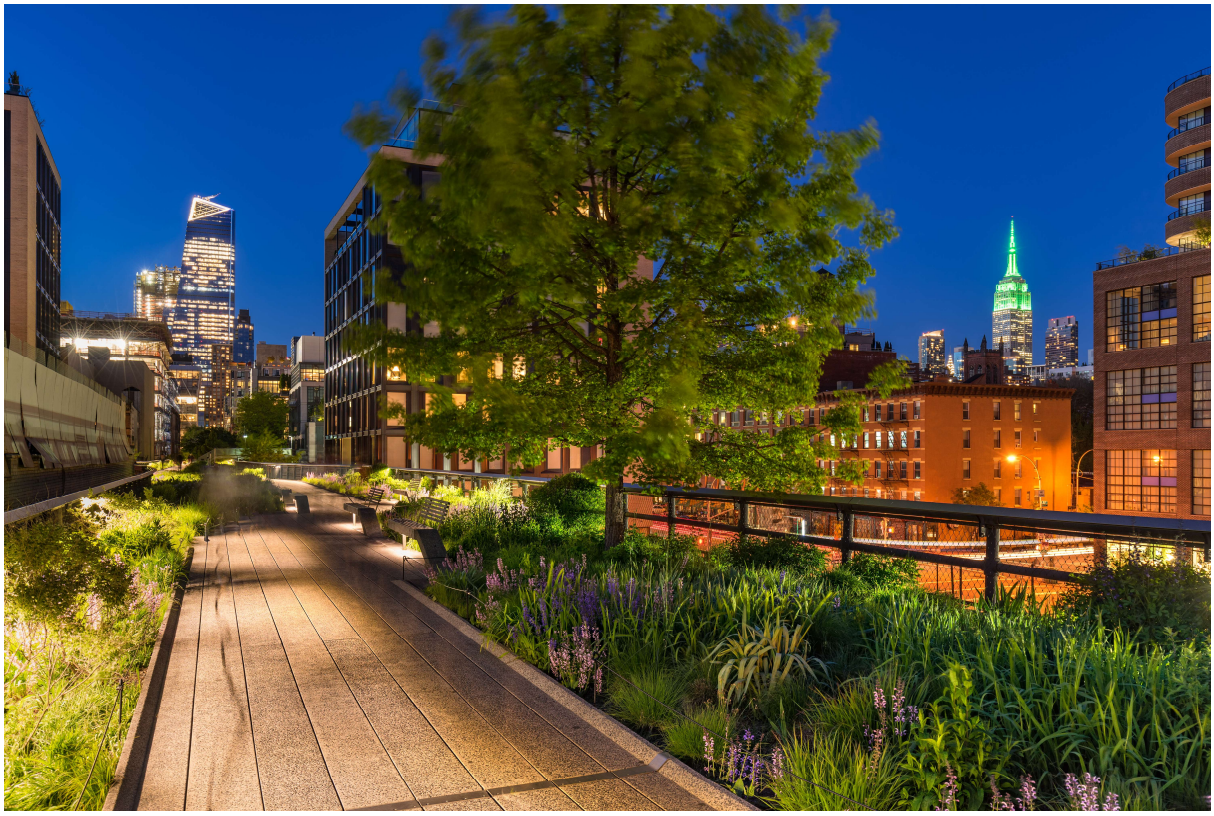

Fig. 3: Furniture- and handrail-integrated LED lighting in The High Line, New York/USA (Photographer: Francois Roux; Source: https://www.istockphoto.com)

Table 5: Dark-Light Analysis of Case Study # 3

	High Line, New York/USA	Measurement Index
1.	Does the project discreetly integrate history to preserve the cultural heritage and tradition of the night sky for future generations?	Yes (Minimal upward light from the lighting system)
2.	Does the project enterprisingly utilise resources to ensure the efficient and sustainable use of lighting for saving energy and money as well as preserving non-renewable resources?	Yes (Minimal use of energy from the lighting system)
3.	Does the project methodically riposte nature to preserve a direct connection to nature beyond the human world?	Yes (Maximal connection to nature with accentuated vegetation)
4.	Does the project objectively fraternize societies to promote happiness and healthiness for human emotional and physiological wellbeing?	Yes (Maximal human comfort from the lighting system)
5.	Does the project sensitively acclimate paradoxes to protect and preserve the biodiversity of different species?	No (Accentuated vegetation may disturb different species)
6.	Does the project imaginatively explore regulations and opportunistically mutate ideas to preserve the beauty and visibility of the stellar night sky?	Yes (Minimal upward light from the lighting system)

5. Discussion

The analysis of three popular projects in outdoor lighting as case studies of biodiversity protection, darkness preservation, heritage conservation, and social interaction with the dark-light design has revealed several aspects

about these projects. All three case studies adequately meet the two ideological concept-values of enterprisingly utilising resources to ensure the efficient and sustainable use of lighting for saving resources, and objectively fraternizing societies to promote human emotional and physiological wellbeing. One probable reason could be that clients, designers, and end-users are making conscious efforts towards better utilisation of resources, and enhanced feelings of wellbeing for users. Case studies # 1 and 3 adequately meet the two ideological concept-values of discretely integrating history to preserve cultural heritage, and imaginatively explore regulations and opportunistically mutate ideas to preserve beauty and visibility of night sky. This is considering the fact that the lighting systems for both these case studies have been designed to emit minimal upward light. Case study # 1 is the only project that adequately meets the ideological concept-value of sensitively acclimating paradoxes to protect and preserve the biodiversity of different species. This is because the light spectrum of the lighting systems was specifically designed to cause minimal disturbance to bats and fireflies. Case studies # 2 and 3 adequately meet the ideological concept-value of methodically riposting nature to preserve a direct connection to nature beyond the human world. The perforated sphere and accentuated vegetation were specifically designed to provide an abstract and direct connection respectively to nature.

The upward light from the spheres and tree canopies in case study # 2 is an impediment in meeting the ideological concept-values of discretely integrating history to preserve cultural heritage, and imaginatively exploring regulations and opportunistically mutating ideas to preserve beauty and visibility of night sky. Similarly, the illuminated tree canopies and vegetation in case studies # 2 and 3 respectively are impediments in meeting the ideological concept-value of sensitively acclimating paradoxes to preserve different species. Finally, case study # 1 is the only project that does not meet the ideological concept-value of methodically riposting nature to preserve a direct connection to nature beyond the human world. The probable reason for these case studies not being able to meet the respective concept-values could be that these projects were not being designed with a particular focus towards preserving cultural heritage, night skies or different species. This further justifies the need for a dark-light design framework that can be used as a checklist and guidance tool to meet all the necessary concept-values while designing outdoor spaces.

6. Conclusion

The paper has established that as outdoor spaces continue to change and evolve, careful design of darkness and light can be a step towards ecologically, economically and socially sustainable design. However, it is important to note that the paper neither provides taxonomies on historical design movements, nor on design styles. It merely seeks to identify and learn from what has been observed about pragmatic utopian lighting design and darkness values, which might be inspiring for those operating in the realm of designing and planning outdoor spaces. Various cities across the world are beginning to pass relevant ordinances towards biodiversity protection, darkness preservation, heritage conservation, and social interaction. The cities of New York, USA [53] and Toronto, Canada [54] have recently passed ordinances for all new buildings and significant exterior renovations to include bird-friendly materials and lighting to address the myriad bird deaths per year due to fatal flights into buildings and the obstructed view of the night sky from light pollution. The city of Cambridge, USA [55] installed adaptive lighting controls that enabled the dimming of street lights in selected neighbourhoods down to 30% of maximum output after 10 pm, simultaneously reducing unnecessary impact upon wildlife and reducing energy costs. The city of Chicago, USA [56] on the other hand found ways to create jobs and training opportunities for individuals from economically disadvantaged areas as well as heighten safety in underserved areas while implementing a community-sensitive smart street lighting system. However, cities and urban centres around the world need to carefully plan for darkness and light so as to prepare urban centres for a positive and resilient future. The dark-light design framework might just provide the impetus for such careful planning.

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References

[1] Slade, J. (2021, March). Changing our vocabulary. Lighting Design and Application: LD and A, 51(3), 20–22.
[2] Slade, J. (2021, June). Darkness as a Beacon. Lighting Design and Application: LD and A, 51(6), 18–20.
[3] Slade, J. (2020, November). From Tracks to Trails. Lighting Design and Application: LD and A, 50(11), 22–24.
[4] Bogard, P. (2013). The end of night: searching for natural darkness in an age of artificial light. Hachette UK, 336.
[5] Houser, K. W. (2021). Ethics and Fallacies of Human-Centric Lighting and Artificial Light at Night. Leukos, 17(4), 319-320, from https://doi.org/10.1080/15502724.2021.1951021
[6] Dugar, A. M., & Lewis, T. M. (2014). Pragmatic Utopian Lighting Design: Amodern movement of careful design and conservation. In LIGHTFAIRInternational LFI 2014. Las Vegas, NV, USA.
[7] Dugar, A. M. (2019). Pragmatic Utopian Lighting Design - Classifying amodern architecture movement within the umbrella of sustainable design, andidentifying its parallel lighting movement. InNational Conference on RecentTrends in Architecture & Civil Engineering towards Energy efficiency andSustainable Development (NCACESD) 2019. Tiruchirappalli, INDIA: Departmentof Architecture, National Institute of Technology.
[8] Kasperzyk, D. (1991). Pragmatic Utopias: Planning With Nature. Context Institute, 44.
[9] Ingels, B. (2009). Yes is more: an archicomic of architectural evolution. Cologne, 400 p.
[10] LightingEurope & German Electrical and Electronic Manufacturers' Association (ZVEI). (2013, July). Human Centric Lighting: Going Beyond Energy Efficiency. A.T. Kearney, from https://www.lightingeurope.org/images/publications/general/Market_Study-Human_Centric_Lighting._Final_July_2013.pdf
[11] Slade, J. (2018, September). Starving for Darkness. Lighting Design and Application: LD and A, 48(9), 62–65.
[12] Slade, J. (2019, June). The Hidden Toll. Lighting Design and Application: LD and A, 49(6), 30–32.
[13] Slade, J. (2019, March). Clear Skies Ahead. Lighting Design and Application: LD and A, 49(3), 14–15.
[14] Slade, J. (2019, November). The Lungs of the Earth. Lighting Design and Application: LD and A, 49(11), 26–28.
[15] Riley, W. D., Bendall, B., Ives, M. J., Edmonds, N. J., & Maxwell, D. L. (2012). Street lighting disrupts the diel migratory pattern of wild Atlantic salmon, Salmo salar L., smolts leaving their natal stream. Aquaculture, 330, 74-81.
[16] Moore, M. V., Pierce, S. M., Walsh, H. M., Kvalvik, S. K., & Lim, J. D. (2000, October 1). Urban light pollution alters the diel vertical migration of Daphnia. SIL Proceedings, 1922–2010, 27(2), 779-782.
[17] Wiltschko, R., Stapput, K., Thalau, P., & Wiltschko, W. (2010). Directional orientation of birds by the magnetic field under different light conditions. Journal of the Royal Society Interface, 7(suppl_2), 163-177.
[18] Aulsebrook, L. C., Bertram, M. G., Martin, J. M., Aulsebrook, A. E., Brodin, T., Evans, J. P., ... & Wong, B. B. (2020). Reproduction in a polluted world: implications for wildlife. Reproduction, 160(2), R13-R23.
[19] Miller CR, Barton BT, Zhu L, Radeloff VC, Oliver KM, Harmon JP, et al. Combined effects of night warming and light pollution on predator–prey interactions. Proc R Soc B.
[20] Chepesiuk R. (2009). Missing the dark: health effects of light pollution. Environmental health perspectives, 117(1), A20–A27.
[21] Stevens, R. G., & Zhu, Y. (2015). Electric light, particularly at night, disrupts human circadian rhythmicity: is that a problem?. Philosophical Transactions of the Royal Society B: Biological Sciences, 370(1667), 20140120.
[22] Spivey, A. (2010). Light pollution: light at night and breast cancer risk worldwide. Environmental health perspectives, 118(12), a525.
[23] Park, Y. M. M., White, A. J., Jackson, C. L., Weinberg, C. R., & Sandler, D. P. (2019). Association of exposure to artificial light at night while sleeping with risk of obesity in women. JAMA internal medicine, 179(8), 1061-1071.
[24] Obayashi, K., Saeki, K., Iwamoto, J., Ikada, Y., & Kurumatani, N. (2014). Independent associations of exposure to evening light and nocturnal urinary melatonin excretion with diabetes in the elderly. Chronobiology international, 31(3), 394-400.
[25] Methorst, J., Rehdanz, K., Mueller, T., Hansjürgens, B., Bonn, A., & Böhning-Gaese, K. (2021). The importance of species diversity for human well-being in Europe. Ecological Economics, 181, 106917.
[26] Macgregor, C. J., Pocock, M. J., Fox, R., & Evans, D. M. (2019). Effects of street lighting technologies on the success and quality of pollination in a nocturnally pollinated plant. Ecosphere, 10(1), e02550.
[27] Knop, E., Zoller, L., Ryser, R., Gerpe, C., Hörler, M., & Fontaine, C. (2017). Artificial light at night as a new threat to pollination. Nature, 548(7666), 206-209.
[28] Palmer, M., Gibbons, R., Bhagavathula, R., Holshouser, D., & Davidson, D. (2017). Roadway lighting's impact on altering soybean growth (No. FHWA-ICT-17-010).

[29] Fouquet, R., & Pearson, P. J. (2012, January 1). The long run demand for lighting: elasticities and rebound effects in different phases of economic development. Economics of Energy & Environmental Policy, 1(1), 83-100.
[30] Fotios, S., & Gibbons, R. (2018). Road lighting research for drivers and pedestrians: The basis of luminance and illuminance recommendations. Lighting Research & Technology, 50(1), 154-186.
[31] Steinbach, R., Perkins, C., Tompson, L., Johnson, S., Armstrong, B., Green, J., ... & Edwards, P. (2015). The effect of reduced street lighting on road casualties and crime in England and Wales: controlled interrupted time series analysis. J Epidemiol Community Health, 69(11), 1118-1124.
[32] Narisada, K., & Schreuder, D. (2004). Aim and purpose of outdoor lighting. In Light Pollution Handbook (pp. 37-59). Springer, Dordrecht.
[33] Schreuder, D. (2008). Outdoor lighting: physics, vision and perception (Vol. 448). Dordrecht: Springer.
[34] Fotios, S., Unwin, J., & Farrall, S. (2015). Road lighting and pedestrian reassurance after dark: A review. Lighting Research & Technology, 47(4), 449-469.
[35] Narboni, R. (2004). Lighting the Landscape : Art Design Technologies (1st ed.) Birkhäuser. 230 p.
[36] Stone, T. (2018). The value of darkness: A moral framework for urban nighttime lighting. Science and engineering ethics, 24(2), 607-628.
[37] Coxworth, B. (2018, June 9). Dutch town goes with bat-friendly streetlights. New Atlas. Retrieved May 20, 2018.
[38] Halper, M. (2018, June 30). Holland's newest red-light district is a big boost for bats. LEDs Magazine. Retrieved June 3, 2021.
[39] Rowse, E. G., Lewanzik, D., Stone, E. L., Harris, S., & Jones, G. (2016). Dark matters: the effects of artificial lighting on bats. In Bats in the Anthropocene: Conservation of bats in a changing world (pp. 187-213). Springer, Cham.
[40] Spoelstra, K., van Grunsven, R. H., Ramakers, J. J., Ferguson, K. B., Raap, T., Donners, M., ... & Visser, M. E. (2017). Response of bats to light with different spectra: light-shy and agile bat presence is affected by white and green, but not red light. Proceedings of the Royal Society B: Biological Sciences, 284(1855), 20170075.
[41] Spoelstra, K., Ramakers, J. J., van Dis, N. E., & Visser, M. E. (2018). No effect of artificial light of different colors on commuting Daubenton's bats (Myotis daubentonii) in a choice experiment. Journal of Experimental Zoology Part A: Ecological and Integrative Physiology, 329(8-9), 506-510.
[42] Sanders, D., & Gaston, K. J. (2018). How ecological communities respond to artificial light at night. Journal of Experimental Zoology Part A: Ecological and Integrative Physiology, 329(8-9), 394-400.
[43] Costin, K. J., & Boulton, A. M. (2016). A field experiment on the effect of introduced light pollution on fireflies (Coleoptera: Lampyridae) in the Piedmont Region of Maryland. The Coleopterists Bulletin, 70(1), 84-86.
[44] Owens, A. C. S., Meyer-Rochow, V. B., & Yang, E.-C. (2018, February 7). Short- and mid-wavelength artificial light influences the flash signals of Aquatica ficta fireflies (Coleoptera: Lampyridae). PLOS ONE.
[45] Payne, S. (2012, January 5). Slow Shutter Fireflies by Tsuneaki Hiramatsu. The Coolist. Retrieved June 22, 2021, from https://www.thecoolist.com/slow-shutter-fireflies-by-tsuneaki-hiramatsu/
[46] Gonchar, J., & Lentz, L. C. (2017, March 8). Dark-Sky Design: Queen Elizabeth Olympic Park. Architectural Record. Retrieved June 18, 2021, from https://www.architecturalrecord.com/articles/11818-dark-sky-design-queen-elizabeth-olympic-park
[47] Donoff, E. (2015, August 11). 2015 AL Design Awards: Queen Elizabeth Olympic Park, London. Architect Magazine. Retrieved July 5, 2021, from https://www.architectmagazine.com/al-design-awards/2015-al-design-awards-queen-elizabeth-olympic-park-london_o
[48] Casciani, Daria & Rossi, Maurizio. (2012). ELSE, Experience of Lighting Sustainability in the Environment. In Cumulus 2012: "Open, participative cities: how design knowledge can support public services in the development of open, participative human environment". Helsinki, FINLAND; 2012.
[49] Pandharipande, A. (2020). Connected lighting and societal impact. Lighting Research & Technology, 52(5), 581-581.
[50] Mullaney, J. (2014, May 21). Illuminating the High Line. High Line. Retrieved September 12, 2021, from https://www.thehighline.org/blog/2014/05/21/illuminating-the-high-line-2/
[51] Gonchar, J., & Lentz, L. C. (2016, August 1). Dark-Sky Design: The High Line. Architectural Record. Retrieved September 13, 2021, from https://www.architecturalrecord.com/articles/11820-dark-sky-design-the-high-line
[52] Gerrish, G. A., Morin, J. G., Rivers, T. J., & Patrawala, Z. (2009). Darkness as an ecological resource: the role of light in partitioning the nocturnal niche. Oecologia, 160(3), 525-536.
[53] New York, USA. (2020). Bird friendly materials. The New York City Counsil. from https://legistar.council.nyc.gov/LegislationDetail.aspx?ID=3903501&GUID=21B44B73-D7E1-4C55-83BD-1CA254531416&Options=&Search=
[54] Toronto, ON, CANADA. (2016). Bird-Friendly Guidelines. City of Toronto. https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/design-guidelines/bird-friendly-guidelines/
[55] Cambridge, MA. (2016). Setting the example for adaptive street lighting. Echelon Corporation. from https://www.echelon.com

[56] Taggart, S. (2021, June). Chicago Style. Lighting Design and Application: LD and A, 51(6), 36–38.