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Title: Rethinking Streetlights:

Copenhagen's Bus Stops through Perception, Movement,

and Urban Identity

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A.C Meyers Vænge 15,

DK-2450 Copenhagen SV Semester

Coordinator: Georgios Triantafyllidis
Secretary: Lisbeth Nykjær

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Supervisor(s): Morteza Hosseini

Project group no.:

Members:
Irem Yuksel
Veronica Rodriguez-Rial

Abstract: This thesis sees the bus stop not just as a shelter, but as a moment in the city's rhythm. Scattered across Copenhagen, these microscale urban fragments are passed, approached, and paused at—by pedestrians, cyclists, and buses—each with a different speed, a different lens. Yet despite their frequency and role as essential public nodes, bus stops often dissolve into the city's nighttime fabric and unlike train stations, squares, or other urban public spaces, they rarely have a dedicated lighting strategy.

This project asks: How can a lighting strategy that responds to urban movement turn waiting time at bus stops into a safer and more visually engaging urban experience? It frames the bus stop as a site of perception, movement, and urban identity - an in-between place shaped by both presence and passage.

The research identifies three lighting parameters: brightness, contrast, and distribution, as key to enhancing the perceived qualities of comfort, safety, space awareness and legibility. Each parameter is analyzed through mixed methods (behavioral observation, simulations, interviews…) and tested against specific perceptual outcomes across diverse user rhythms.

The outcomes of this thesis are sequential. It first proposes a lighting strategy based on three principles: Balance brightness so the space supports rather than overwhelms; Introduce backlighting to gently signal human presence; Calibrate direction so each user—on foot, by bike, or behind the wheel—can recognize the stop when it matters most. These principles then inform a concrete design proposal that applies them spatially in a context specific solution, in which through these interventions, the bus stop is reimagined as a designed moment - revealing not only its own presence, but its role in the image of the city.

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Rodriguez-Rial Veronica, Yuksel Irem.

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KEY WORDS: Streetlights, Bus stop, Perception, Movement, Urban identity.

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CHAPTER I: INTRODUCTION

1. Introduction

1.1 Context

Urban lighting is a critical component of how cities function and are experienced after dark. It serves practical needs and shapes the way people perceive and engage with their surroundings. While dedicated public spaces - such as parks, squares or even train stations - often receive dedicated lighting strategies, smaller transit nodes like bus stops are frequently neglected within broader urban lighting plans.

Traditionally, bus stops were designed as purely functional elements as a pole, they grew offering basic shelter and the current design included a resting area based on a bench. Over time, it can be seen that their architectural role has evolved, and in cities like Copenhagen, bus stops now contribute to the city's urban character and aesthetics. These stops are part of the transportation network and simultaneously function as everyday public spaces. They are experienced differently depending on the user: pedestrians engage with them frequently and up close, cyclists encounter them briefly but often, and buses approach them constantly throughout the day.

Bus stops can occupy a unique position in the city: they are widely distributed, and embedded in everyday routines. In a dense urban setting like Copenhagen, the large number of stops create a visual rhythm along streetscapes—making them an important part of the city's image. These micro-scale environments that are modest in size, can have a cumulative and meaningful impact.

Yet, as Solaris notes, "Typically, a bus stop is approached in purely technical terms. A few glass walls displaying the timetable, a bench for waiting comfortably and a canopy to protect against rain. Bus transfer points usually function as a kind of storage container for people waiting to be transported to another point, where time is inevitably lost" (Solaris, n.d.). This purely functional approach overlooks the spatial and visual roles bus stops play in the everyday urban experience.

As part of Copenhagen's extensive public transport network, bus stops can be more than just waiting points. The starting point of this thesis is the thought that they could contribute significantly to the city's nightscape and influence how the city is perceived and understood after dark.

1.2 Problem:

Despite their presence, frequency, and integration in the urban rhythm, bus stops have remained peripheral in lighting design practice. While their architectural and infrastructural roles have evolved to reflect contemporary urban values—through transparency, modularity, and integration into streetscapes—their lighting continues to be treated as a secondary or purely technical element. Current lighting at bus stops is typically inherited from adjacent streetlights or advertising panels, neither of which is designed to consider how people actually experience these spaces: by waiting, approaching, or passing by.

This disconnection between spatial use and lighting strategy results in a missed opportunity. At night, bus stops disappear visually from the city's nighttime identity. Without lighting that responds to perceptual needs, user behavior or spatial context, these highly distributed urban elements are unable to contribute meaningfully to the experience of the street.

The problem is not the absence of light, but the absence of lighting design—an intentional, human-centric approach that uses light as a tool to rethink how these small spaces contribute to street lighting. This thesis addresses this gap by investigating how lighting at bus stops can be designed to respond to perception, movement, and urban identity, transforming these often-overlooked micro-spaces into meaningful urban moments.

1.3 Objectives and scope

1.3.1 Objectives

The primary objective of this thesis is to rethink the role of lighting at bus stops by exploring how light can be used as a design tool to enhance perception, support movement, and express urban identity, transforming these micro-scale transit spaces into active contributors to Copenhagen's nighttime experience.

Building on this exploration, the secondary objective is to develop a site-specific lighting design proposal that offers a possible conceptual solution to reposition the bus stop as an active and engaging element within the urban fabric.

1.3.2 Scope

The scope is defined by the following categories:

User Typology

The project considers three primary user groups: pedestrians, cyclists, and bus drivers. Each group interacts with the bus stop differently depending on speed, distance, and functional needs. Their distinct perspectives are used to evaluate how lighting impacts across various approach conditions.

Spatial Context

The study is set within the urban boundaries of Copenhagen, specifically focusing on bus stops along Line 2A. As such, it operates within the constraints of Copenhagen's street lighting master plan, urban fabric, and existing architectural typologies of the city's bus stops. The architectural form and materiality of these shelters are considered as fixed elements, with lighting strategies developed in response to these spatial and regulatory conditions.

Design Exploration

The thesis is grounded in lighting design, not in architecture. However, minor architectural adjustments may be proposed when required to support or embed the lighting concept. These interventions are intended to be as minimal as possible, with a focus on maintaining the existing structure and character of the stop.

Temporal Focus - Nighttime Conditions

The project focuses exclusively on nighttime perception and visibility. Daylight conditions, seasonal variation, and the integration of natural light are beyond the scope of this research. All analyses, tests, and design proposals are developed to address challenges and opportunities related to artificial lighting at night.

Sustainability Focus

The project takes a social sustainability perspective by emphasizing the role of everyday urban spaces in shaping the quality of life in the city. It recognizes that well-considered interventions in common, small-scale environments can foster a stronger perception of urban identity . While environmental factors such as light pollution are acknowledged, they are not part of the research focus and are therefore not addressed in depth.

Infrastructure Boundaries

The lighting strategy developed in this thesis applies only to elements within the physical boundary of the bus stop. It does not propose changes to road infrastructure, urban furniture, or surrounding street lighting. However, in the lighting simulations, existing street lighting conditions have been accounted for, particularly in terms of their ambient influence (light pollution) on the bus stop area, to reflect realistic lighting scenarios.

By narrowing the study to lighting as the primary medium, this thesis aims to generate insights that are applicable to the design of under-addressed micro-scale urban spaces. The project does not attempt to provide a universal solution but instead offers a focused approach that can inform future lighting interventions in similar everyday settings, where perception, movement and urban identity might be overlooked.

1.4 Structure of the thesis

This thesis follows the IMRaD structure—Introduction, Methods, Results, and Discussion—but is adapted to integrate a design-led research process. Each chapter builds progressively from conceptual framing and field observations to the development and evaluation of a site-specific lighting proposal for a bus stop in Copenhagen.

1. Introduction

Introduces the broader urban and infrastructural context that motivates the study. It identifies the bus stop as an overlooked but socially meaningful public space, and frames the research scope and objectives. Furthermore it includes the structure and conceptual framework of this study.

2. Literature Review

This chapter is divided into three conceptual blocks—*Perception*, *Movement*, and *Urban Identity*—and three analytical blocks—*Brightness*, *Contrast*, and *Distribution*. These sections bring together theoretical texts and recent lighting studies to construct a lens through which the theoretical and analytical framework of this research is built. This chapter also informs the criteria used to interpret field observations and guide design decisions.

3. Methodology

Presents the research design. Introduces a series of quantitative, qualitative and mixed methods analysis linked to three sub-research questions and to the lighting parameters under investigation. Specific emphasis is placed on the chosen case study: the Glyptoteket bus stop on Line 2A in Copenhagen.

4. Results

The first part of this chapter unveils the lighting design strategy built through the research driven approach. It begins by explaining the conceptual foundation of *revealing*, followed by the strategy of the layered lighting system organized into three sections (Atmosphere and Presence, Rhythm, and Image of the City) which correspond directly to the literature review theoretical blocks and sub-research questions. The second part of the chapter includes detailed diagrams, section drawings, and DIALux simulations of the final design proposal.

5. Discussion

Reflects on how each sub-research question contributed to the development of the final design, and critically assesses the limitations and potentials of the proposal. It also discusses the broader implications of using lighting as a tool for narrative placemaking in transit infrastructure. Also Outlines possible next steps, including in-situ prototyping, dynamic or adaptive lighting systems, and the potential to apply the same design logic to other bus stops or microscale in-between public spaces in the city.

6. Conclusion

Summarizes the key design findings and their relationship to the original research aim. It highlights how the proposal offers a subtle but meaningful shift in how bus stops are experienced at night within their urban context.

CHAPTER II: LITERATURE REVIEW

2. Literature Review

This chapter presents the conceptual and analytical background guiding the thesis. It is divided into three sections. The first section, *Conceptual Framework*, defines the design terms and intentions.

The second section, *Theoretical Foundations*, explores three key themes that emerge from the literature: Perception, Movement, and Urban Identity. These conceptual blocks structure the review and inform how lighting is understood not merely as a technical requirement, but as a spatial and social agent that shapes human experience at bus stops.

The third section, *Analytical Foundations*, identifies specific lighting parameters—brightness, contrast, and distribution—as independent variables, and connects them to perceptual qualities such as comfort, perceived safety, space awareness, and legibility. These relationships are examined through the lens of multiple empirical and theoretical studies. Together, they form the foundation on which this research builds its analytical framework—identifying how specific lighting parameters influence human-centered outcomes and informing the evaluation of design strategies.

2.1 Conceptual Framework

Bus stops are typically perceived as functional infrastructure—defined by their utility rather than their spatial or visual qualities. However, as shown in the preceding chapters, these micro-scale environments hold latent potential to influence how the city is perceived, especially after dark. If lighting is approached not merely as a means of illumination but as a design material, the bus stop can be reimagined as more than a space to wait. It can become a pause to enjoy the city's nighttime experience. This chapter introduces the vision that frames this thesis:

"*Imagine if a bus stop was not only a waiting spot but a designed moment in the city.*"

2.1.1 A designed moment

"Designed" refers to a deliberate intervention within the environment that opposes conditions of boredom, where "boredom is maintained by an environment that is perceived as static, with the actor remaining largely disconnected from the processes that comprise his or her environment" (Watt, 1991, p.326).
Instead, "a designed" actively engages users through perceptual experience, understood as an event perceived in the moment, created by sensory impressions from the outside world (Jantzen et al., 2012, in Madsen, 2015–2016, p.50).

Perceptual experience can be direct — based on the individual's perception and interaction with the outside world(Nielsen, 2021, p.42) — and, in urban contexts, manifests through the visual appearance of urban spaces as performatively engaging (Ebbensgaard, 2015, p.1912).
This is linked to the process of perception, which "refers to the process where stimuli are selected, organized, and interpreted" (Solomon, Askegaard, & Bamossy, 2019, p.86).

Therefore, "a designed" implies an intentional activation of sensory, cognitive, and spatial engagement, breaking the static disconnection of boredom, and provoking a visual perceptive experience rooted in direct interaction with the urban environment.

The term "moment" captures the temporality and immediacy of the experience. It can be understood as "glimpses, windows, aperture, or revelations," moments of heightened awareness that punctuate everyday experience (Mason, 2018, p.193).

A designed moment is then defined as an intentional activation of perceptual and sensory engagement in an urban environment, breaking static disconnection (boredom) and creating a temporary, heightened experience ("glimpses, windows, aperture, or revelations") within the flow of everyday life.

2.1.2 A bus stop

Following the previous reflection about designed moments, it is necessary to question whether In the city a bus stop — in its traditional form — is a space or a place.

According to Heineken (2017, p.77):

"The difference between a place and a space is the people. When people start to come and connect with space it is called a place."

Yet, in many cases, bus stops remain spaces: anonymous, transitional points lacking identity or emotional connection. They often align with Marc Augé’s (1995, p.94) definition of non-place:

"A place without a story, a generic and homogeneous space, leaving no impressions of the users."

At a bus stop, the act of waiting frequently reinforces this sense of disconnection. Waiting itself happens outside the experience of place: In static, disconnected environments where individuals are detached from the processes around them, boredom arises Watt (1991)

Therefore, bus stops, understood through the lenses of non-place and boredom, risk being perceived not as places but as spaces of transit, void of engagement.

However, bus stops also contain a profound potential:
If reimagined through engagement, design, and perceptual experience, they could align with the notion of in-between spaces. As Sundbo & Sørensen (2013, p.453) define:

"In-between spaces are spaces where the premises of everyday life are put on hold; these spaces have potentials of transformative experiences, changing the way we perceive the space."

In this sense, a bus stop — rather than merely being a non-place — could become an in-between-place:

A site where the act of waiting is no longer passive but performative, breaking the static boredom associated with *non-places.*

A site that intercepts the everyday routine with designed moments, triggering sensory perception and meaningful experience.

A site that invites perceptual and emotional engagement, transforming itself into a place - a space carrying identity, memory and human connection..

2.1.3 In the city

After discussing what it means to design a moment, and how it can transform a bus stop from a non-place to an in-between space, it becomes essential to reflect on what it means for this event to occur in the city. The city is more than an assembly of buildings, streets, and infrastructures; it is a dynamic fabric of perception, memory, and collective identity where lighting plays a fundamental role in shaping the urban image. As Kutlu and Manav (2013, p.82) observe, *"Lighting can serve as an organizer and conveyer of spatial hierarchies while giving a visual identity to a city."* Light is therefore an active participant in the construction of place identity.

City branding strategies further articulate this potential, when lighting is used to amplify the perceived image of the city as stated in *Lighting Branding* (p.140), *"City branding could be applied to neighborhoods, districts, tourist destinations, cities, rural areas, regions, and countries. Creating place identity by increasing perceived image. Lighting shows a new and different image of the building during the night."*

Yet the impact of light is not limited to visual aesthetics; it deeply affects emotional and social sensibility. Lighting interventions can foster what Ebbensgaard (2014, p.125) defines as space awareness: *"People becoming more emotionally and socially sensitive to their urban environment."* This sensitivity is a catalyst for place-making, where individuals navigate the urban fabric while they actively connect with it and with each other. In Ebbensgaard’s words, place-making is about *"people becoming more emotionally and socially sensitive to their urban environment and to others,"* creating a less egoistic atmosphere by encouraging an outward-looking urban sensibility that transcends isolated personal experiences.

In order to evaluate possible interventions, the impact of the bus stops lighting design in the perceived urban identity cannot be studied without taking into account its surroundings, existing in a co-presence with the urban street lighting and therefore calling for context specific solutions within the city. It is within this broader urban context that the bus stop finds its renewed meaning. Previously considered a functional space aligned with the characteristics of a non-place, the bus stop — reimagined as a designed moment — becomes an active participant in the urban nightscape. Lighting design can help the bus stop transcend its traditional role as a space of passive waiting, and instead contribute to the visual identity of the city. It can enhance space awareness at the micro-scale, foster communal feelings among those who gather there, and provide an illuminated, emotional encounter with the city itself. By implementing a perceptual experience into a formerly static and anonymous setting, the bus stop transforms into an in-between-place — no longer a subject to boredom, but a moment in the urban narrative, awakening identity, community, and meaning within the everyday image of the city.

To translate the vision of transforming the bus stop into a designed moment in the city, it is necessary to identify measurable lighting variables, building an analysis and design criteria that define the experience of the space. These criteria are built through the literature and will guide the analysis of the current situation, as well as the design of test-based interventions.

2.2 Theoretical Foundations

The literature review is structured around three conceptual blocks that reflect the key themes of this thesis: Perception, Movement, and Urban Identity. Together, these guide the evaluation of how lighting transforms the experience of waiting at bus stops and serve as the foundation for the analytical phase and design strategy.

2.2.1 Perception

Perception is central to understanding how lighting impacts the experience of waiting at bus stops. Numerous studies underscore that lighting affects not only visibility but also emotional and physiological responses such as comfort and perceived safety. For example, Hvass and Hansen (2022) demonstrated that brightness levels and their hierarchy significantly influence feelings of safety and visual comfort in public transport areas. Rather than advocating for uniformly high lighting levels, several studies emphasized the importance of balanced brightness and controlled transitions, which foster spatial clarity and reduce glare or feeling of exposure (Hvass et al., 2021; Amoruso et al., 2022).

Lighting also has a psychological effect on space awareness—how users understand their position in the environment and perceive the boundaries of a space. Ebbensgaard (2015) emphasized that lighting influences social presence and visibility in ways that go beyond luminance, affecting emotional and sensory perception. When lighting levels are too high or contrast is poorly managed, users may feel visually isolated from their surroundings, resulting in discomfort or anxiety (Hvass & Hansen, 2020). Thus, lighting becomes a perceptual agent that mediates perceived safety, comfort, and space awareness.

2.2.2 Urban Identity

Beyond individual perception, lighting also contributes to the broader image of the city. Mahdavinejad et al. (2020) discussed how lighting functions as an instrument of urban branding and identity formation. They argued that architectural lighting not only enhances recognition of landmarks but also shapes the "nocturnal identity" of cities. This insight is particularly relevant for transit spaces like bus stops, which often lack distinctiveness and are treated as utilitarian objects. Reframing them through lighting as meaningful urban moments can contribute to the city's legibility and character.

Ebbensgaard (2015) similarly described how illuminated environments in Copenhagen influence sensory memory and place-making. Lighting is not merely a tool for visibility but a material that frames emotional and social experiences of the city. The notion of the bus stop as a "non-place" can be contested by designing lighting that integrates the stop into the urban fabric, making it part of the city's nighttime rhythm and aesthetic language. In this sense, lighting becomes a means of increasing urban legibility—a concept rooted in Kevin Lynch's (1960) definition of imageability.

2.2.3 Movement

Movement is a critical framework for evaluating lighting design at bus stops, particularly because users approach and interact with the space at varying speeds—on foot, by bike, or from vehicles. As Ahmed (2017) and Thibaud (2011) pointed out, movement alters how lighting is perceived, especially in transitional or layered public spaces. Fast-moving users require long-range visibility and legible silhouettes, whereas pedestrians need visual cues for orientation and comfort at close proximity.

Lighting must adapt to these changing perceptual needs. Amoruso et al. (2022) emphasized that excessive brightness can disrupt dark adaptation, causing discomfort for pedestrians and cyclists alike. Meanwhile, studies like Farmer et al. (2024) and Phillips et al. (2021) linked poor lighting to reduced driver compliance and increased collision risks at stops, reinforcing the importance of perceived safety for fast-moving users.

Ebbensgaard (2015) and Pink and Sumartojo (2018) also observed that light modulates sensory rhythms during movement, transforming passive travel into a sequence of perceptual "glimpses." Movement-responsive lighting strategies—those that reveal information dynamically—can therefore support recognition, anticipation, and spatial integration across all user groups.

2.3 Analytical Foundations

Building upon the theoretical blocks above, several studies examined the relationship between independent lighting parameters—particularly brightness, contrast, and distribution—and dependent perceptual qualities such as comfort, perceived safety, space awareness, and legibility. These relationships are not uniform across the literature but reveal consistent patterns when mapped across the three theoretical dimensions.

2.3.1 Mapping Parameters by Theme

Perception → Comfort, Perceived Safety, Space Awareness
Studies consistently demonstrated that brightness hierarchy and smooth luminance transitions reduce glare and discomfort, enhancing comfort (Hvass et al., 2021). Contrast and backlighting improve presence recognition and thus perceived safety (Farmer et al., 2024).Safety needs emerge from the spatial and perceptual predictability that lighting can create. Perceived safety is not only a function of light levels but also of contrast relationships and visual reach. Rahm & Johansson (2018, p.1) define it as *"the subjective experience of feeling safe, which is influenced by lighting conditions — especially the lighting of the local space where a person is situated and the ability to perform long-range detection of potential threats."* Spaces that allow users to view their surroundings with clarity, without sudden shadows or dark corners, enhance control and trust. Carefully calibrated contrast and indirect lighting help users feel both seen and connected to the surroundings without being exposed.

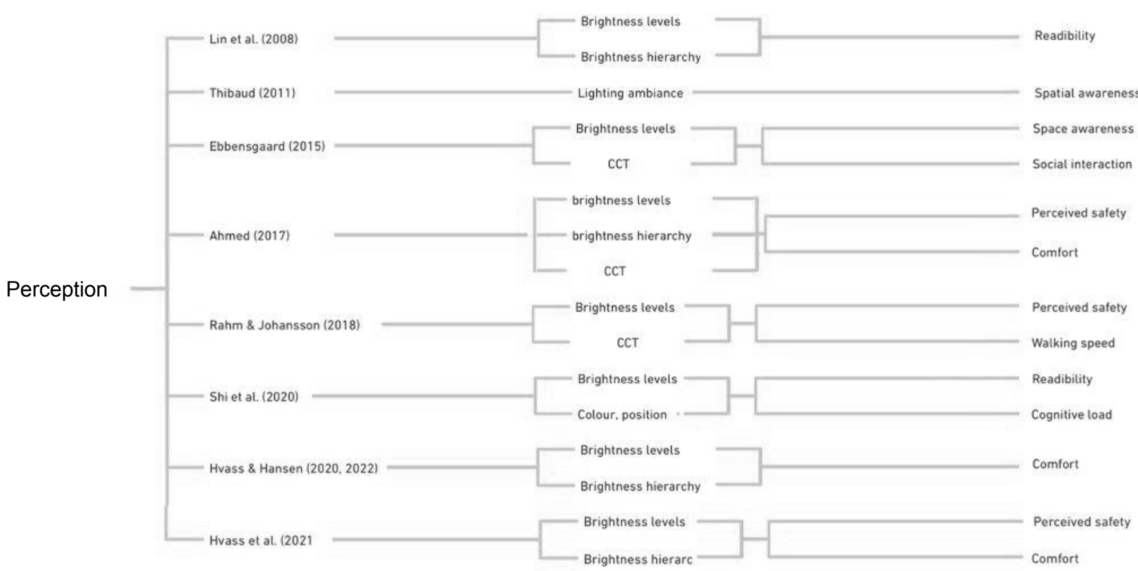


Figure 01. Theoretical foundations. Perception: Independent variables - perceived qualities of light.

Distribution of light across surfaces shapes space awareness by reinforcing or dissolving spatial boundaries (Amoruso et al., 2022; Ebbensgaard, 2015).

Urban Identity → Legibility
In this block, contrast and distribution are key to supporting legibility—the ability to recognize and orient within space. Lynch's concept of imageability is extended to lighting through recognizable visual cues (Mahdavinejad et al., 2020).

Movement → Comfort, Perceived Safety, Space Awareness, Legibility
Because users interact with bus stops at varying speeds, all four dependent variables must be considered together. Directionally responsive lighting calibrated to speed and approach angles supports legibility, enhances comfort, and improves perceived safety through earlier recognition and reduced glare (Ahmed, 2017; Amoruso et al., 2022). Even light distribution along the approach path ensures space awareness and perceptual continuity (Ebbensgaard, 2015).

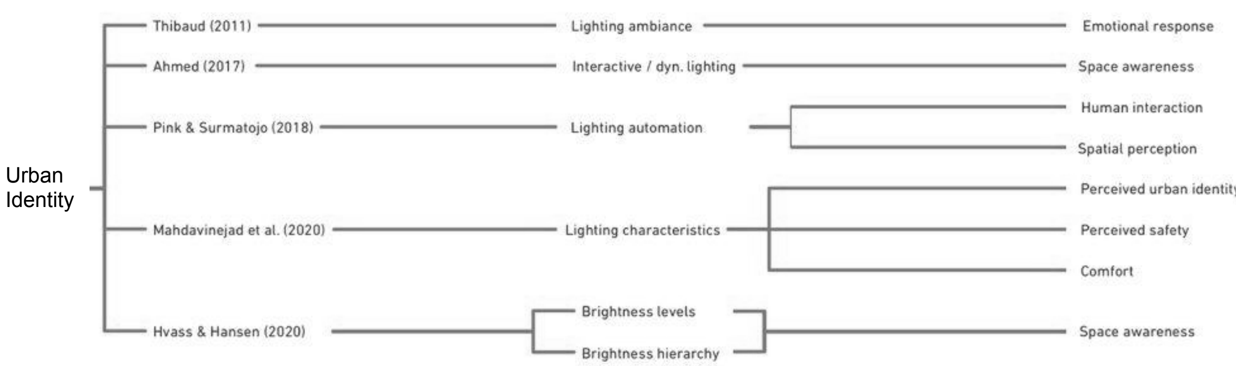


Figure 02. Theoretical foundations. Urban identity : Independent variables - perceived qualities of light.

2.3.2 Analytical Framework

This section synthesizes the findings into a clear operational framework that will guide the analysis and design phase. It categorizes which dependent variables are most strongly influenced by each independent variable, clarifying the focus of each sub-research question and simulation test.

Brightness

→ Comfort

→ Perceived Safety

→ Space Awareness

Contrast

→ Perceived Safety

→ Comfort

→ Legibility

Distribution

→ Space Awareness

→ Legibility

→ Comfort

Literature consistently identifies *brightness* as a primary condition for user comfort. People feel more at ease in spaces where lighting is sufficient to separate foreground from background and reveal relevant spatial elements. According to Moyer (2005, p.19), *"If the boundaries of the space are visible for the user, the user will feel more comfortable."* This is reinforced by findings in *How Urban Lighting Can Influence Humans* (p.58), where brightness is listed as one of the four key variables contributing to comfort: *"Enough brightness is the essential attribute for people to feel comfortable. When the lighting provides good contrast and sufficient brightness at night (by making objects visible and not letting them mix into the background), people feel comfortable in that area."* Hvass and Hansen (2022), Hvass et al. (2021), and Amoruso et al. (2022) investigated its influence on users' subjective feelings of comfort and safety in both field and lab settings. Their methods included luminance mapping, perceptual surveys, and walk-along interviews. They consistently found that well-balanced brightness levels (rather than higher intensity) increased spatial comfort, while imbalanced luminance hierarchies caused glare and feelings of vulnerability. Brightness was also linked to perceived safety by enabling clear facial visibility and visibility of others in the environment.

Contrast was examined by Farmer et al. (2024) and Amoruso et al. (2022) in relation to how people and objects are perceived under different light intensities and backgrounds. Studies used visual simulations, driving experiments, and presence recognition tests to evaluate contrast. These showed that contrast plays a critical role in perceived safety, particularly for fast-moving users like drivers and cyclists who need to detect silhouettes from a distance. High contrast was beneficial for presence visibility, but only when controlled—otherwise it led to discomfort. The literature cautions against high contrast when it isolates the user or increases visual tension: *"Where brightness, legibility, and distribution are increasing, people feel more comfortable, but where we have higher contrast, people feel less comfortable."* The implication is that contrast must be calibrated — enhancing definition and silhouette without compromising the user's comfort or spatial integration. These fundamentals are especially relevant in public spaces where visual perception must support a variety of micro-activities, from reading signage to observing movement, while allowing people to remain relaxed and aware of their surroundings.

Distribution was explored by Ebbensgaard (2015) and Ahmed (2017) through ethnographic observations and user-centered design analysis. They focused on how light is delivered across the space and how this influences users' spatial orientation. Their findings highlighted that uneven distribution creates disorientation and reduces the ability to read spatial boundaries, while more consistent and directional light supports both space awareness and legibility. Distribution was also tied to comfort when light was too concentrated in one area or created visual imbalance.

This framework enables the research to structure its analysis around targeted variables, ensuring that each lighting intervention is evaluated with respect to its specific perceptual effects. The goal is to develop a human-centered lighting strategy that responds not only to visibility but also to how light shapes the experience of waiting, recognition, and movement in public space.

CHAPTER III: METHODOLOGY

3. Methodology

This chapter presents the research field and research design process that structure the development of the lighting proposal. The research question is explored through a series of quantitative, qualitative, and mixed-methods analyses, each connected to one of the three lighting parameters—brightness, contrast, and distribution—and to the corresponding perceptual qualities: comfort, space awareness, perceived safety, and legibility. These analyses lead to the breakdown of the RQ into three sub-research questions, which will be assessed individually to isolate the parameters that represent them and after combined in a layered result in the next chapter.

3.1 Research Question (RQ)

The research question emerges from the combined insights of the conceptual, theoretical and analytical framework developed in Chapter 2. Through the lens of *designed moments*, bus stops were reimagined not as a place to wait, but as opportunities for engagement and experiencing the city.

As a means, the bus stop's role within the context of perception, movement and urban identity demands a lighting strategy that is not static but responsive to urban movement. This strategy should enhance visual quality, but also contribute to a safer and more legible urban environment, especially during the vulnerable act of waiting.

Framed by these findings, the central research question of this thesis is:

"How can a lighting strategy that responds to urban movement turn waiting time at bus stops into a safer and more visually engaging urban experience?"

3.2 Defining the Research Field

Urban Context & Bus Stop Typologies

Copenhagen's public bus system provides essential mobility across the city and plays an important role on the city's transportation network. Unlike metro and train lines that follow fixed corridors, buses operate flexibly within the urban street grid and offer connectivity to areas that are not directly served by rail infrastructure. The bus network has dense and extensive lines, intersecting a wide range of urban environments—from residential neighborhoods to commercial zones and industrial areas. These lines serve as a transport infrastructure that structures daily urban rhythms, shaping how people move through and experience the city.

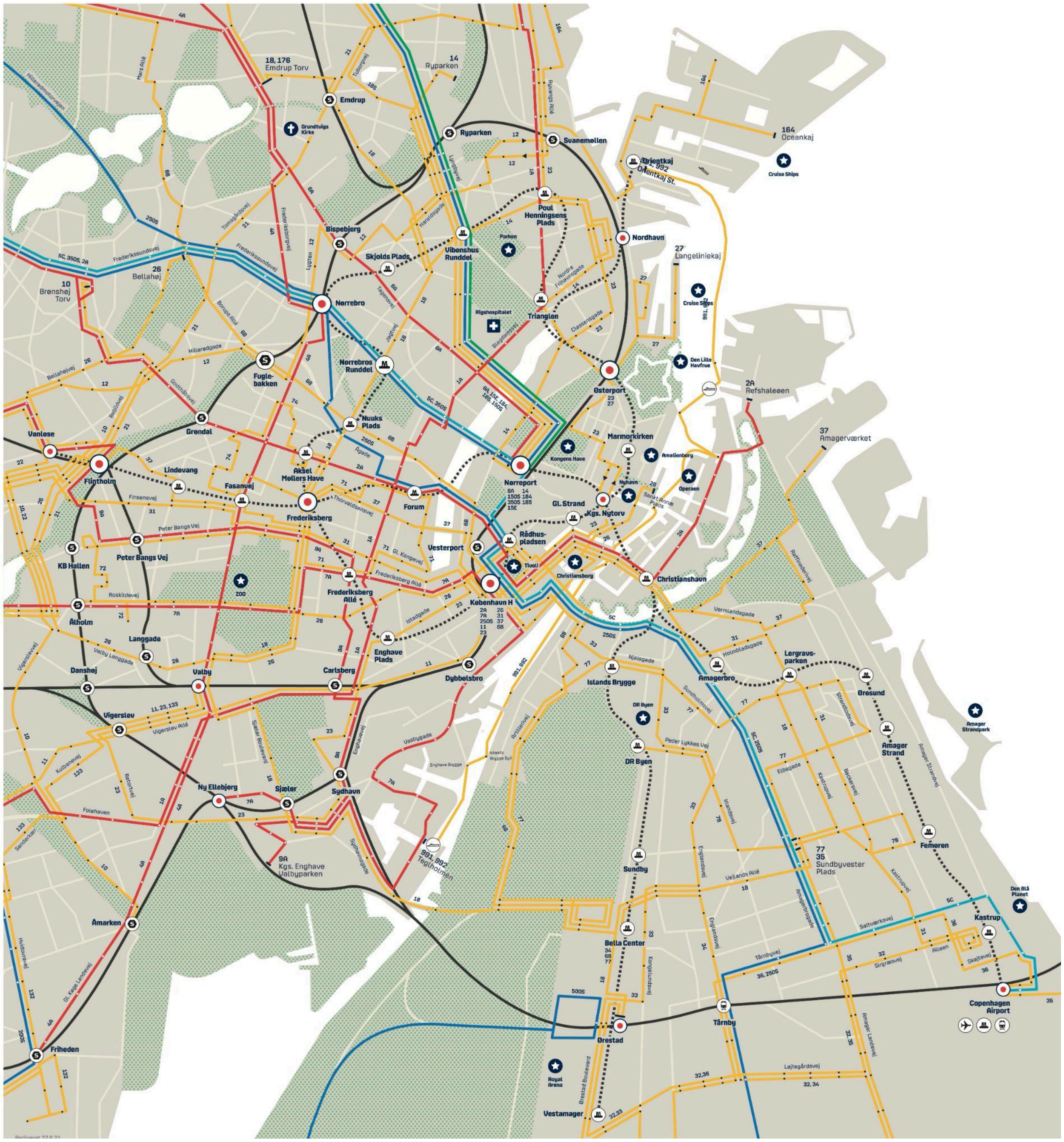


Figure 03: Map of public transportation in Copenhagen, highlighting bus, metro, and train routes. *Image source: Amherst College Global Education Blog (2020).*

Aiming to narrow the lighting research within a manageable frame, this project focused on one representative bus line: Line 2A. This line was chosen for practical and analytical reasons. Practically, it allowed for fieldwork, user observation, and consistent data collection along a defined route. Analytically, it was selected due to its coverage of a wide range of urban contexts—making it a case study for exploring lighting needs and spatial experiences under varying conditions. As shown in *Figure 03*, Line 2A begins in the residential district of Tingbjerg and travels through commercial, cultural, and recreational zones before ending in the post-industrial landscape of Refshaleøen. To structure the contextual understanding of the line, five urban zone types were defined:

Residential zones are primarily composed of housing and are characterized by low evening activity, minimal commercial frontage, and subdued ambient lighting. These areas prioritize privacy, quietness, and a sense of security.
Commercial zones include streets lined with shops, offices, and services. They are more brightly lit and active into the evening, requiring visibility for storefronts, signage, and pedestrian circulation.
Recreational zones consist of parks, sports grounds, and public green areas. These are often darker after sunset, with limited ambient lighting and intermittent user activity.
Industrial zones host logistics, light manufacturing, or storage facilities. These areas may be less populated at night but often contain harsh artificial lighting for operational purposes.
Cultural zones include theatres, museums, historical landmarks, and educational institutions. Lighting in these areas contributes not only to visibility but also to mood, orientation, and the framing of architectural or historical features.

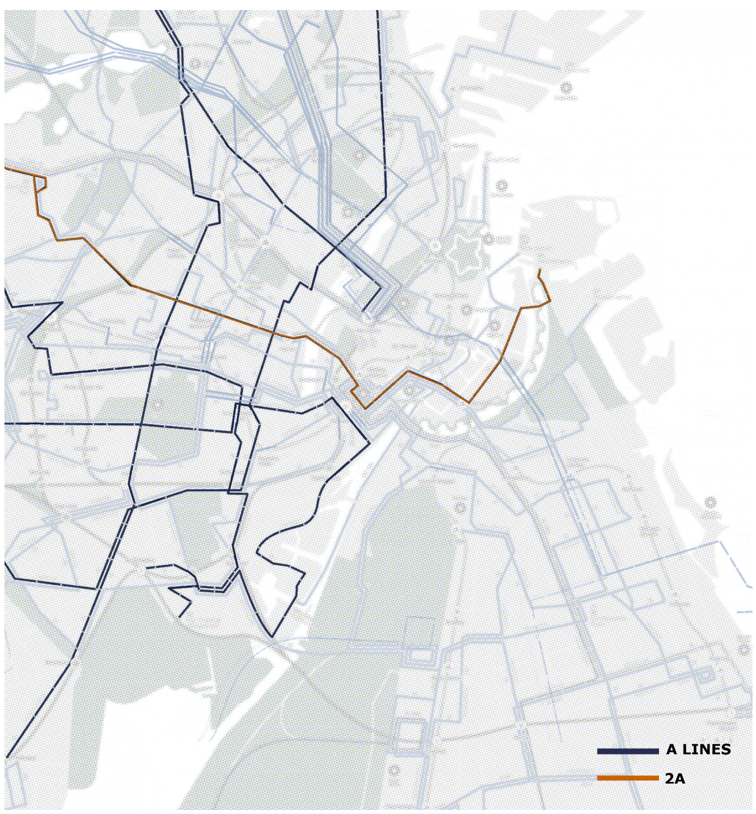


Figure 04: Map of A-bus lines and 2A

Each stop of Line 2A was categorised on these five categories to better understand the environmental context in which each bus stop operates. This allowed the research to be established in a reference framework for the context-specific lit environment, ensuring that lighting design proposals respond appropriately to the typical ambient conditions present at each stop typology. In addition to urban zones, it was necessary to define the types of bus stops found along the line. Copenhagen's bus infrastructure generally falls into three categories:

Pole stops consist of a post displaying the route number and timetable, often with no dedicated lighting or seating.
Shelter stops include a semi-enclosed structure with a roof, side walls, and usually a bench. These often include illuminated advertising panels.
Cluster stops serve multiple routes and are often located near major transit junctions. They may include multiple shelters or larger platforms.

Figure 05. Pole type bus stop

Figure 06. Shelter type bus stop *Image source: Holscher Design (n.d.). Retrieved from* *https://holscherdesign.com/cases/afa-jcdecaux-copenhagen/*

Figure 07. Cluster type bus stop *Image source: Alamy (2022). Retrieved from https://www.alamy.com/copenhagen-denmark-june-14-2022-the-copenhagen-central-station-bus-stop-image473105281.html*

For the purposes of this research, the study focused on shelter-type bus stops. This decision was made based on both their architectural relevance and their perceptual complexity. Shelter and Cluster stops offer a semi-enclosed space that users can physically enter, that makes their experience of lighting more immersive than at pole stops. They also involve multiple materials and light-reflecting surfaces—glass, metal, and pavement—which interact differently with lighting design. Moreover, shelter stops provide more consistent parameters than the cluster typology for analysis (fixed dimensions, defined enclosure, presence of seating), allowing for more reliable comparison across sites and user types. In addition to these qualitative and analytical advantages, the choice was also informed by the fact that the majority of bus stops along Line 2A fall under the shelter typology, making them the most representative condition for this study's scope.

A detailed classification of all 38 stops along Line 2A—including their stop type, urban zone designation, and brightness measurements—is included in Appendix A.

In order to conduct in-depth analysis and simulation testing, one specific stop was selected as the representative case: the Glyptoteket bus stop (Line 2A, direction Refshaleøen–Tingbjerg Gavlhusvej). This location was chosen based on its combination of architectural features and urban context. It is a shelter-type stop located in a central, culturally significant area near museums and major pedestrian flows, making it suitable for evaluating lighting design both in terms of spatial perception and contextual integration. Its proximity to bicycle infrastructure, and integration with a cultural urban zone provided a rich setting for observation and testing across different user types.

Additionally, within this framework the analysis focused on three user profiles: pedestrian, cyclist, and bus driver. These groups were selected to reflect the diverse perceptual conditions and movement speeds encountered in the urban nightscape. Pedestrians engage directly with the bus stop—entering, waiting, or passing by at close range—making their experience of spatial comfort and lighting clarity critical. Cyclists, although not passengers, regularly interact with the spatial field of the bus stop as part of their commuting path. They perceive the stop dynamically, and are directly affected by lighting contrasts, pedestrian movement, and legibility around the stop. Cyclists often share space with bus users, and the legibility of the stop can influence both their safety and reaction time. Bus drivers approach the stop at higher speeds, requiring early and clear recognition of the stop itself and any waiting passengers.

By narrowing the research to a single bus line—Line 2A—with diverse urban zone types, and focusing on the shelter typology, the study established a clear framework for investigating lighting in bus stop environments. Within this framework, three user profiles were examined: pedestrians, cyclists, and bus drivers. Each represents a different speed and mode of interaction with the space, allowing the study to explore how lighting conditions shape comfort, safety, legibility and space awareness across varied movement patterns. This targeted approach enabled an understanding of both the challenges and opportunities in designing lighting strategies for micro-scale urban infrastructure like bus stops.

3.3 Analysis & Synthesis

This chapter aims to bring together a range of analytical methods to assess the current lighting conditions of a selected bus stop along Copenhagen's 2A line. The purpose of these analyses is to understand how light shapes user experience—both functionally and perceptually—across different types of engagement. Lighting at the bus stop is examined from multiple perspectives: through technical performance, user perception, movement, and behavior.

The chapter is structured around three analysis methods: quantitative, qualitative, and mixed methods. The quantitative analysis investigates the existing luminance and illuminance hierarchy using lighting simulation tools to measure and visualize how brightness, contrast and distribution are distributed across the space, and how each lighting layer affects the perception of the bus stop. The qualitative analysis intends to capture user perspectives through interviews with pedestrians, cyclists, and a bus driver, revealing how light influences feelings of safety, comfort, spatial awareness and legibility. The mixed-methods section combines sequential speed-based visibility studies and behavioral observations to evaluate how lighting affects movement-based recognition and physical positioning within the space.

Each analysis focuses on variables identified earlier in the literature review—brightness, contrast, and distribution—and how these lighting parameters influence perceptual outcomes such as spatial awareness, legibility, comfort, and safety. By drawing from multiple types of data, this chapter creates the foundation for formulating the study's three sub-research questions. These sub-research questions will guide the development and testing of targeted lighting design strategies in the next phase.

The chapter concludes with a synthesis of the findings, identifying the recurring challenges across all methods and highlighting which aspects of the current lighting practice may have room for improvement . The synthesis focuses on acting as a bridge between research and design, providing a clear direction for how a research-driven lighting strategy can respond to perception, movement and urban identity in a micro-scale public setting.

3.3.1 Quantitative Analysis - Luminance and Illuminance analysis

3.3.1.1 Existing conditions

To understand how lighting conditions affect visual comfort and spatial legibility at the Glyptoteket bus stop (Line 2A, direction Refshaleøen–Tingbjerg Gavlhusvej), a luminance and illuminance analysis was conducted using DIALux Evo. This analysis focused on brightness levels, distribution patterns, and their possible visual effects on the user environment under nighttime conditions. As noted in *(Appendix A)* the bus stop is located in a commercial-cultural urban context, where ground-level ambient light pollution was measured at 8 lux. This value reflects contributions from suspended road lighting and tall-standing sidewalk poles, though the last sources are partially obstructed by mature trees. There is no significant facade lighting behind or around the shelter, due to the presence of a vegetation wall at the rear which sits at a slight distance from the shelter and a two-lane road separating it from other buildings.

To analyze the lighting conditions, the bus stop and its immediate surroundings were modeled in DIALux Evo using accurate site-based geometry and material data. Since the exact model of lighting fixtures used by the municipality could not be identified, a range of luminaires with similar characteristics were tested and iteratively adjusted until the simulated luminance values closely matched field measurements taken in real-world conditions. The final configuration used in the model included:

- Overhead road lighting at approximate urban scale heights
- A retro illuminated advertising panel simulated using a calibrated area light
- Directional spotlights within the shelter's roof structure

The performance of these light sources was evaluated based on measured illuminance at four reference surfaces:

1. Surface 1 – 1 m² horizontal surface in front of the advertisement panel, positioned 1.00 m away (≈80 lx)
2. Surface 2 – 1.00 × 0.40 m vertical plane facing the ad panel at 1.60 m height, positioned 1.00 m away (≈62 lx)
3. Surface 3 – Horizontal bench surface inside the shelter (≈119 lx)
4. Surface 4 – 1 m² horizontal surface on the sidewalk opposite the ad panel (≈10.5 lx)

These results are visualized in the false-color illuminance map and the false-color luminance simulation (Fig. 08) , both of which were validated against falsecolouring HDR-calibrated field photos to ensure accuracy in perceptual representation with a Luminance meter and Aftab software. Since the goal of the analysis was to understand luminance hierarchy and spatial distribution—not absolute photometric output—the simulation was considered valid once its false-color output visually matched the HDR-derived luminance map. This comparative alignment ensured that the simulation reflected the way brightness levels were perceived and structured in space. However, it is acknowledged that if the objective had been to quantify total luminous output or to measure absolute values of brightness across the entire bus stop, having access to the exact fixture specifications would have been necessary. For the purpose of analyzing luminance contrasts and assessing how light is distributed and perceived within the stop, the approximation is considered sufficient and methodologically justified.

The findings from the luminance mapping analysis have interpreted the brightness levels and distribution through a hierarchy. This structure allows the evaluation to move from what is lit to how it can influence users comfort, space awareness and legibility.

The absolute brightest surface across both vertical and horizontal planes is the vertical surface of the advertisement panel (reaches approximately 300lx). This value is nearly 2 times brighter than the second-brightest surface (the horizontal bench at 119 lx). The ad panel thus defines the visual focal point of the space, dominating the perceptual field and drawing attention away from other architectural elements. As a result, it establishes itself not only as a physical object but as the visual anchor of the entire bus stop interior.

The second brightest surface, and the brightest among horizontal surfaces, is the bench surface (119 lx). It is numerically secondary in the space, However, being a narrow, horizontal surface, it is not a dominant element in the bus stop.

In third place the horizontal floor area in front of the ad panel measures 80 lx, still relatively high, but about 30% dimmer than the bench. Meanwhile, the exterior sidewalk opposite the bus stop records just 10.5 lx, the lowest measured value. This results in an almost 1:8 ratio between inside and outside floor surfaces, reinforcing the interior's perceptual brightness dominance right in front of the ad panel, and the mapping shows how uneven it is in relation to the interior of the bus stop itself falling to lx at the opposite end of the interior.

These ratios confirm a lighting scheme that prioritizes one dominant source—the advertisement panel—at the expense of balanced spatial legibility. Illumination is concentrated in isolated areas while adjacent zones remain underlit in comparaison, creating uneven illumination along the surfaces and, preventing the shelter from functioning as a perceptually unified or inviting space.

These results confirm a lighting strategy centered on a single dominant light source, with surrounding zones significantly underlit. The visual field lacks balance, and spatial legibility is reduced by abrupt transitions in brightness. As shown in the illuminance and luminance maps, this lighting scheme results in fragmented perception, where the shelter functions more as a series of isolated elements than as a cohesive spatial unit.

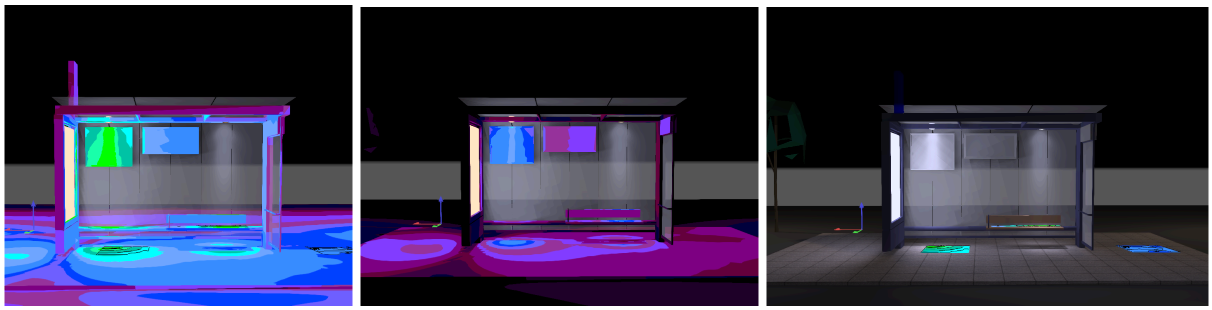


Figure 08: Current lighting simulation: Illuminance, Luminance, Calculus surfaces.

3.3.1.2 Light Layer Contribution Analysis

To better understand how each lighting element influences spatial brightness and legibility, the luminance mapping was repeated with individual lighting layers singled out. This strategy isolates the contribution of each lighting layer aiming to explore how each of them influences the complete outcome in terms of hierarchy. By selectively isolating different luminaire groups, the individual contribution of each lighting layer—streetlights, the advertisement panel, and the shelter's integrated spotlights—was assessed. For each configuration, the three brightest surfaces were identified and their values compared to those measured in the full lighting setup. This approach reveals how each light source influences spatial legibility and comfort based on the brightness hierarchy.

3.3.1.2.1 Streetlights Only

In the first scenario, only the ambient street lighting was active. TIn this configuration, only the ambient street lighting—composed of overhead road and sidewalk luminaries—was active. The three brightest surfaces were:

1. Surface 4 – Sidewalk opposite the shelter: 8.07 lx
2. Surface 1 – Floor in front of the advertisement panel: 2.26 lx
3. Surface 2 – Vertical plane facing the ad panel: 2.04 lx

Compared to the full configuration—where these same surfaces reached 10.5 lx, 80 lx, and 62 lx respectively—there is a clear drop in illumination, particularly on the surfaces closest to and inside the shelter.

The lack of targeted lighting means the shelter itself is not visually defined. Illumination is concentrated on the street and adjacent sidewalks, but the bus stop appears as a dark void rather than a spatial element within the city. The main function fulfilled by this layer is basic ambient visibility, but it does not support perception, spatial clarity, or presence recognition within the shelter, this supports that the bus stop does need additional light layers to the streetlights to reach not only the same level of lighting than the sidewalk has but also to ensure comfortable lighting that allows the user to be aware of its surroundings e.g to easily spot the bench.

With only the street lighting active, the simulation (*Figure 09)* shows a diffuse and low-level illumination concentrated mainly on the sidewalk in front of the bus stop. The interior of the shelter remains largely underlit, with the bench surface dropping to below 5 lx. While this lighting is sufficient to outline the pavement and surrounding ground, it fails to define the bus stop as a spatial or visual destination.

This confirms that municipal street lighting, while functional for general road safety, does not provide the spatial focus or directional clarity needed to enhance visibility, comfort, or perception of the bus stop at night.

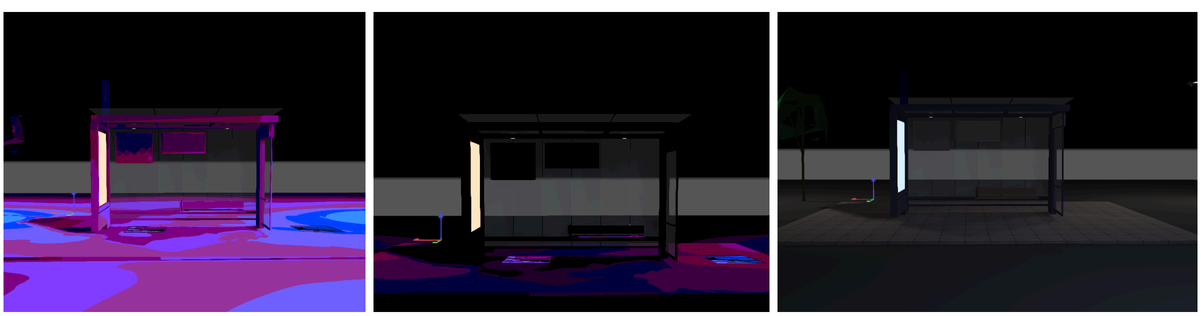


Figure 09: Streetlighting layer simulation: Illuminance, Luminance, Calculus surfaces.

3.3.1.2.2 Streetlights + Advertisement Panel

When the advertisement panel is activated alongside the streetlights (*Figure 10*), the scene shows a dramatic shift in hierarchy. The panel becomes the dominant focal point in the otherwise low-lit environment.

In this configuration, the advertisement panel was activated in addition to the streetlights. The three brightest surfaces were:

1. Surface 2 – Vertical plane facing the ad panel: 115 lx

2. Surface 3 – Bench surface: 14 lx

3. Surface 1 – Floor in front of the ad panel: ≈10 lx

While the panel’s brightness increases visibility from a distance and helps signal the stop’s location, it also creates an unbalanced lighting distribution. The rest of the shelter remains dim, with poor definition of spatial boundaries and limited legibility as it unevens the horizontal distribution blurring the boundaries on the shelter in one half and making them clear in the other half. This configuration prioritizes commercial visibility over user-centric lighting, reinforcing previous findings about the panel's over-dominant presence.

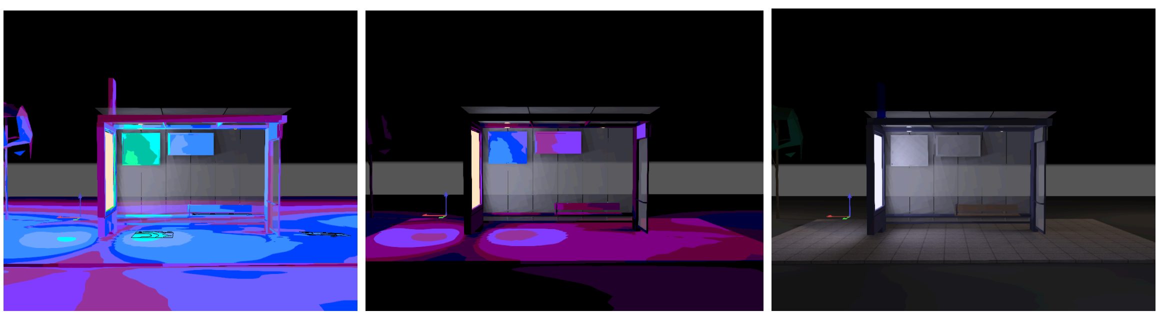


Figure 10: Streetlighting + Panel layer simulation: Illuminance, Luminance, Calculus surfaces.

3.3.1.2.3 Streetlights + Spotlights

In this configuration, the ceiling-mounted spotlights inside the shelter were combined with the ambient streetlights. The three brightest surfaces were:

1. Surface 3 – Bench surface: 68.2 lx

2. Surface 1 – Floor in front of the advertisement panel: 32.2 lx

3. Surface 4 – Sidewalk outside the shelter: 8.47 lx

With the spotlights activated in combination with the streetlights (*Figure 11*), a more even and deliberate lighting distribution begins to appear. The bench surface and interior floor zones become clearly readable, and vertical surfaces—such as the shelter wall—gain enough definition to appear visible. Compared to the advertisement-only setup, this configuration introduces a soft bright gradient from the bottom of the bus stop to blend in with the pavement levels, creating a more welcoming internal atmosphere.

The spotlights contribute to space awareness by revealing surface textures and providing consistent brightness across multiple planes. However, without the visual prominence of the advertisement panel, this layer alone does not create a strong long-distance visual cue. It supports spatial comfort and legibility, especially at pedestrian and cyclist speeds, but still relies on street lights for ambient context and possibly needs a third layer to gain a certain urban identity.

These tests showed that the advertisement panel was responsible for the majority of brightness across all surfaces. Its removal significantly affected the overall distribution. The embedded spotlights contributed local illumination to the bench but lacked sufficient spread to define surrounding space. Meanwhile, the tall-standing sidewalk and suspended road lighting had limited impact on the interior shelter surfaces, offering only general ambient fill.

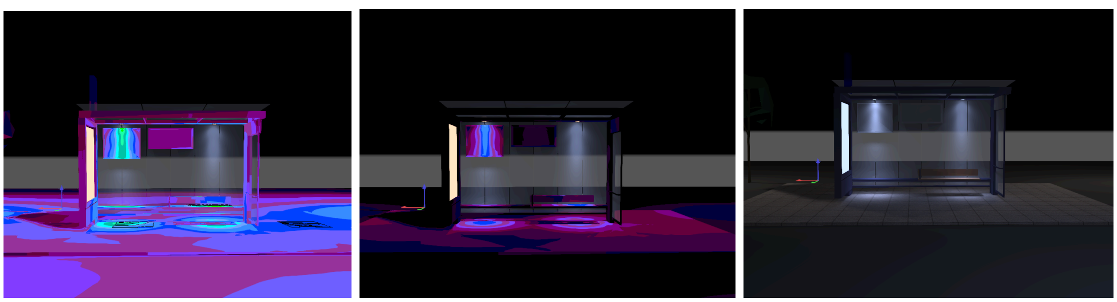


Figure 11: Streetlighting + Spotlights layer simulation: Illuminance, Luminance, Calculus surfaces.

Findings

These simulations demonstrate that each lighting element plays a distinct and limited perceptual role within the bus stop environment. Streetlights offer general ambient coverage but fail to define the shelter. While necessary for general ambient illumination, they are not sufficient to render the bus stop spatially legible. Their diffuse output concentrates on circulation areas outside the shelter, leaving interior elements—such as the bench and shelter walls—underlit and visually disconnected. The advertisement panel, on the opposite end, introduces a strong vertical focal point that enhances the bus stop presence from a distance, however, this comes at the cost of spatial balance and a big impact on the identity of the space since this surface is unrelated to the architecture itself, to the function or to the urban context where it is placed.. The panel dominates the brightness hierarchy creating an uneven distribution that undermines comfort, boundary clarity - and therefore space awareness, and legibility. The spotlights, integrated within the shelter's roof, help re-establish interior coherence by illuminating surfaces destined to be used by waiting passengers, particularly the bench and immediate floor area.

They offer a soft, layered gradient that supports space awareness and close-range usability. Nevertheless, they lack the vertical presence required to make the stop legible from afar.

Taken together, these findings confirm that no single lighting layer can satisfy the full range of perceptual, functional, and contextual needs. A successful lighting strategy for the bus stop must therefore be multi-layered, composed, and calibrated—redistributing brightness across key surfaces, horizontal surface to avoid the lack of spatial clarity or isolation, and integrating targeted vertical cues to support the recognition of meaningful aspects that support urban identity.

3.3.2 Qualitative Analysis - Interviews: Pedestrian, Driver, and Cyclist Perspectives

To better understand how lighting conditions at bus stops are perceived by different types of users, three semi-structured interviews were conducted with individuals who regularly interact with these spaces in different ways: a pedestrian, a cyclist, and a bus driver. Each participant offered insights into how lighting affects their perception of safety, comfort, spatial awareness, and legibility, depending on their proximity, speed, and purpose of engagement with the stop.

The pedestrian (*Appendix B*), commuting from the city center in the early evening hours, described the stop as functionally sufficient (providing a bench and shelter) but visually isolating. While the physical structure met basic needs, the lighting failed to support a sense of comfort or presence. She noted that although there were typically other people around, the dim and cold lighting made her feel detached from her surroundings, as if she were "standing in a box." Her description can highlight the disconnect between the user and the public space when lighting fails to encourage spatial awareness. She expressed a clear preference for a "warmer, cozier" lighting setup that would soften the space visually and make it feel more inviting.

The bus driver (*Appendix C*) offered a complementary perspective grounded in operational needs. Driving Line 2A for several years during evening shifts, he observed that the bus stop itself was generally visible, but people within the stop were not. If individuals stood at the edge of the shelter, they could usually be seen, but those sitting further back or in shadow often went unnoticed until the bus was already pulling in. This may create uncertainty during approach and affect reaction time. The driver attributed this problem to reflection on the glass panels meaning the insufficient contrast between the background and the figures inside the shelter. His remarks underlined the importance of internal lighting directionality and distribution—not just to illuminate the structure but to clearly define its occupants. He proposed subtle but stronger illumination strategies to enhance presence recognition, but expressed that would not wish for a brighter set up, given that it could create an "overwhelming" brightness.

The cyclist *(Appendix D*), who passed the stop daily on his route through the city, reinforced the concern about low legibility. He remarked that the stop tends to visually blend into its surroundings at night unless someone is moving or a bus is present. This blending effect made it difficult to anticipate interaction with people stepping out from the shelter, especially at nighttime conditions. He also commented on the discomfort caused by the sudden brightness of the advertisement panel, which created high contrast against the otherwise dim environment, an effect that was particularly disrupting when passing close by at speed. His comments on possible improvements suggested incorporating a minimal lighting solution that would signal the stop's location and presence from afar, enhancing its legibility without disturbing the visual field.

Together, the interviews revealed a consistent perception of disconnection between the design of the shelter and the experience it offers at night. While the physical structure has evolved to reflect the architectural identity of Copenhagen's public transport system, the lighting remains generic and disconnected from user needs. All three interviewees, despite their differing modes of approach and interaction, pointed to a lack of legibility, reduced user recognition, and a general absence of comfort or space awareness.

More specifically, the interviews emphasized that safety was compromised by low visibility of users inside the shelter, particularly from the perspective of drivers and cyclists. Comfort was impacted by unbalanced brightness that created harsh contrast conditions, especially between the illuminated advertising panels and the rest of the shelter. In terms of space awareness, users indicated that the light distribution caused the boundaries of the bus stop to be vague and visually undefined, making it difficult to perceive it as a distinct space within the urban environment. Lastly, legibility was undermined by the stop's tendency to fade into the street context at night, limiting its recognition until one is in very close proximity.

3.3.3 Mixed Methods

3.3.3.1 Sequential Speed-Based Visibility Studies

This section examines how the bus stop is perceived under motion, considering three common approach speeds—walking, cycling, and driving. The objective is to understand whether the current lighting configuration supports legibility across these conditions and how it may require specific needs based on speed and angle of approach.

To simulate this, a set of visual prompt images was created using Photoshop. Three base images were taken from real angles corresponding to pedestrian (sidewalk), cyclist (bike lane), and driver (road) viewpoints. Each base image *(Figures 12, 14, 16)* was paired with a motion-blurred version *(Figures 13, 15, 17)* to simulate movement. The blur levels were applied according to approximate average user speeds: ~5 km/h for pedestrians (10px blur), ~15–20 km/h for cyclists (25px blur), and ~40–50 km/h for bus drivers (45px blur). These values, though not based on a specific formula, aimed to align with visual communication practices. They emulate increasing speed and decreasing reaction time, reflecting the diminishing capacity to process detail in fast movement.

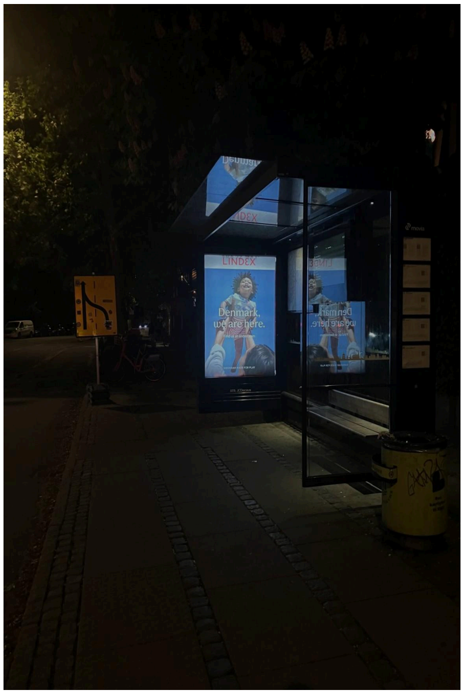
The use of motion blur in this study is based on established visual perception principles. As noted by Navarro et al. (2011, p.1), “motion blur is an important cue for the perception of objects in motion”. Navarro stated that it can act as a visual approximation of how the eye integrates fast-moving scenes. In this context, motion blur serves as an effective and accessible tool for studying the perceptual challenges posed by different speeds.

The visual analysis using motion blur simulation revealed distinct differences in how the bus stop is perceived at varying approach speeds. At pedestrian speed (~5 km/h), legibility of the stop remained largely complete. The structure was perceived as part of the surrounding environment, and details (such as the bench, internal signage, or surface materials) were still distinguishable. This confirmed that at low speeds, lighting elements did not need to be overly prominent to ensure legibility. The area light of the ad panel is the most visible light feature when approaching the stop which flags it to the pedestrian, however, the lack of lighting elements quickly recognisable neglect the identity of the bus stop putting it at the same level of legibility as the standing retroillumination ad panels present around the city. It indicated that the presence of a visually consistent cue linked to the shelter space , could anchor the three dimensional perception, and the need to do so without interfering with comfort when waiting inside.

At cyclist speed (~15–20 km/h), perception began to shift significantly. While the overall form of the shelter was still identifiable, the faster pace reduced the time available for the eye to scan and interpret interior elements. The analysis highlighted that the contrast between the brightly lit advertisement panel and the darker ambient surroundings can draw visual focus away from the human presence inside the stop. This suggests that at intermediate speeds, lighting plays an important role in the safety of the occupants given the immediate connection of the bike line to the bus shelter. In these conditions, light should be carefully distributed to ensure legibility from the bike line angle and to avoid sudden brightness changes at the closest range, while offering a consistent lighting identity through the movement.

At bus approach speed (~40–50 km/h), legibility was most challenged. From this distance and angle, the stop needed to be recognizable as a structure (indicating the stop) and as an occupied space. However, the simulation revealed that at high speeds, only the lit advertisement panel remained clearly visible. In terms of functionality, the effects of the current lighting in the shelter undermannins the main function of the space: Under unoccupied conditions it renders the space hard to perceive given the two dimensional character of the Ad panel lighting, making it difficult for the driver to differentiate them from the standing ad panels distributed around the city; under occupied conditions, it renders the recognition of presence inside the bus stop confusing due to the lack of clear space boundaries that make it hard to differentiate pedestrians from waiting passengers.

In conclusion, the analysis confirmed that current lighting strategies at the bus stop do not sufficiently support legibility and presence recognition across different movement speeds. Each user type—pedestrian, cyclist, and bus driver—interacts with the space differently and requires distinct visual cues to interpret its function. These findings emphasize the need for lighting distribution that offers long-range legibility from a variable range of angles (bike, bus) and contrast-enhancing to help silhouettes stand out without overexposing the space. Additionally, these interventions must be balanced with the pedestrian and waiting passengers' needs of a balanced brightness at a close range, calling for a directionally specific distribution of brightness.



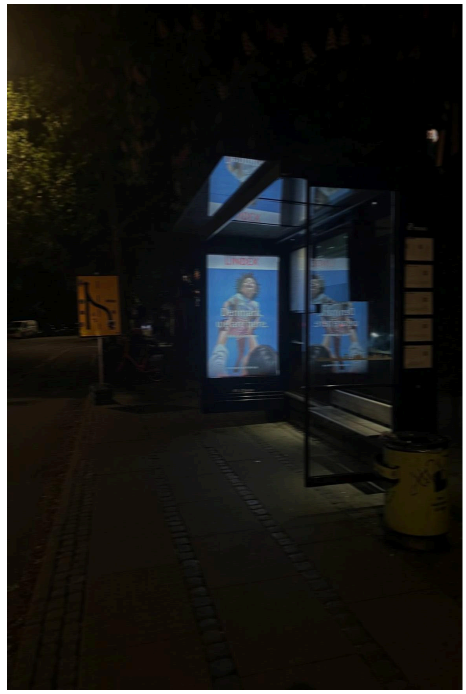
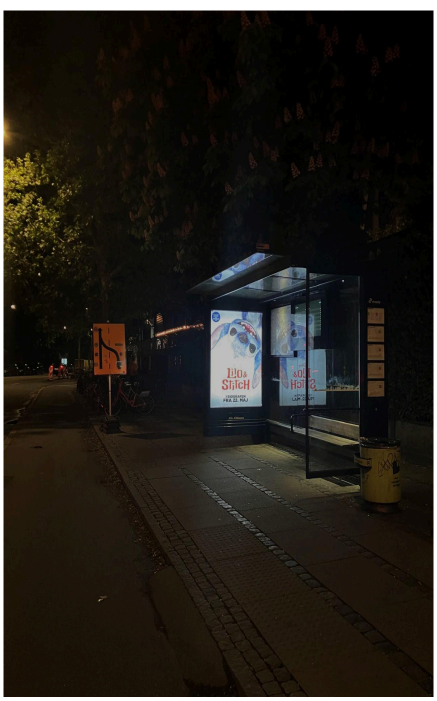


Figure 12. Base image, **Figure 13.** simulated pedestrian motion



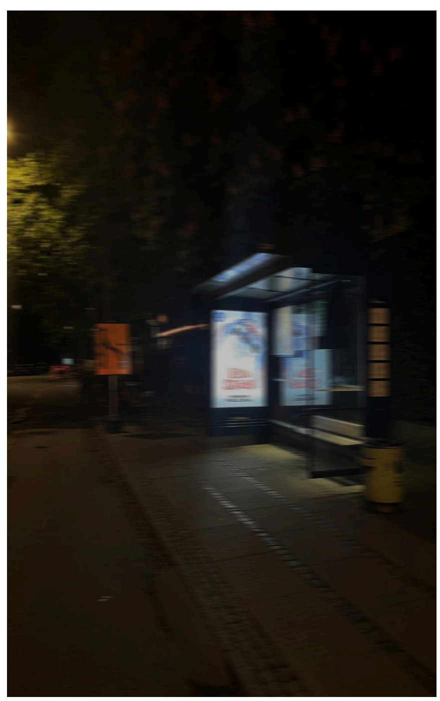


Figure 14. Base image, **Figure 15.** simulated cyclist motion

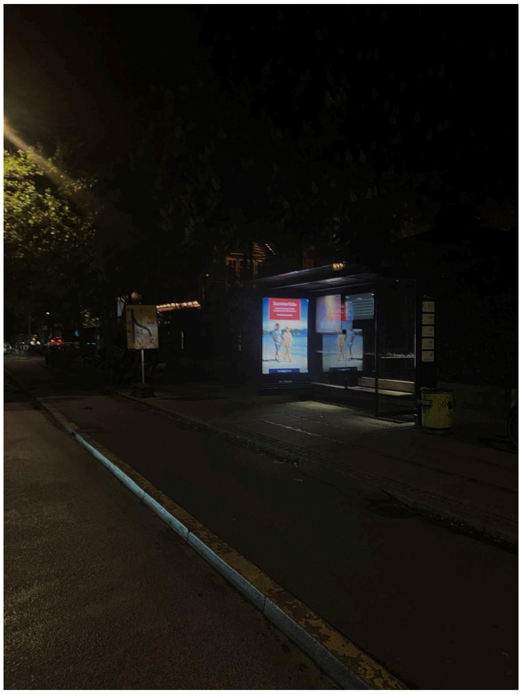
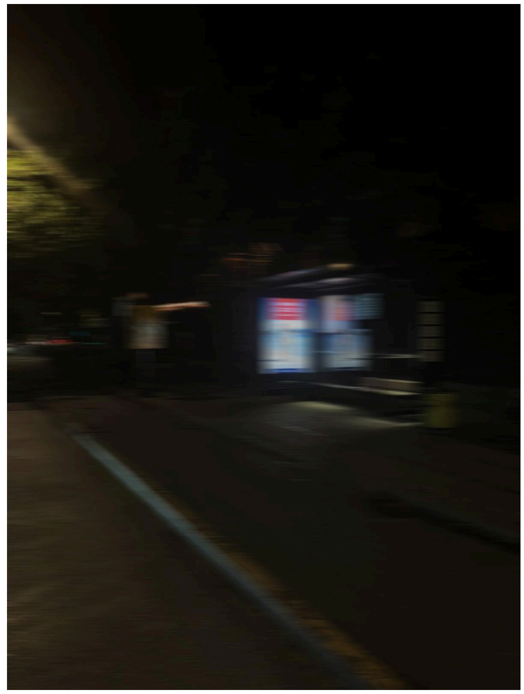



Figure 16. Base image, **Figure 17.** simulated bus driver motion

3.3.3.2 Behavioral Observation of User Interaction and Positioning

This part of the analysis aimed to investigate how lighting conditions at night influence user behavior at the bus stop—specifically, where individuals choose to position themselves, how they orient in relation to light and perception, and how these factors affect space awareness.

The study was conducted at the Glyptoteket bus stop under conditions of well-trafficked road with moderate evening activity from both pedestrians and cyclists. Two evening observation sessions were carried out: one on Friday, April 11 (19:30–21:00), and the other on Saturday, April 12 (20:30–22:30). These timeframes were chosen to capture behavior during the transition into nighttime, when artificial lighting becomes dominant and both commuting and social movement overlap. Users were observed based on their positioning in five spatial zones: Inside the shelter, in front of it, next to it on the sidewalk, near the advertisement panel, and behind the shelter. Notes were also taken on whether individuals were alone, in pairs, or in groups, and on the nature of their interaction and movement. The full breakdown of the sessions can be seen in *Appendix E and F*.

Across both sessions, 49 individuals were observed. The majority were alone, particularly earlier in the evening, while pairs and small groups became more frequent later—especially on Saturday, when evening social activity in the area increased.

The most preferred location was in front of the shelter facing the street. The location allowed users to maintain visual contact with approaching buses while having a relatively well-balanced lighting condition. The openness of the site appeared to promote orientation and freedom of movement. In comparison, the interior of the shelter was occupied selectively and typically for a short duration. When in use, people hung around the entrance rather than sitting down. The inside of the shelter did not appear to offer visual comfort or spatial connection.

The pathway surrounding the shelter was also used often. This area was commonly selected by people waiting alone, being busy with their phones, or preferring a subtle level of separation from others. Its comparatively softer ambient light rendered the area a neutral, multipurpose space for short-term occupation or passive waiting.

The space in front of the advertisement panel, the brightest area, was generally avoided. Some people stepped briefly into this area and continued onward. This reaction indicates that visual discomfort resulted from the contrast between the intensely-lit panel and darker adjacent spaces and made the space uncomfortable for waiting.

The space behind the shelter was occupied only briefly and most frequently by people who seemed to want privacy or separation from the social space. Its darker, more hidden location added to a lack of spatial legibility and made the space inhospitable to long-term use.

Phone use was the most common activity among individuals. Others stood quietly, scanned the street, or conversed in small groups. Group behavior was most often concentrated at the front of the shelter or on the sidewalk. In contrast, the ad panel and the rear side of the shelter were consistently underused, reinforcing the impact of lighting quality on spatial engagement.

In conclusion, behavioral patterns across both evenings reflected an intuitive response to lighting conditions. While soft and evenly distributed lighting encouraged users to occupy certain zones, especially in front of the shelter near the road, direct and high-intensity lighting—particularly from the advertisement panel and spotlights on the bench—was perceived as uncomfortable, leading to consistent avoidance of those areas. This trend of users preferring the ambient lighting outside the shelter over the brighter, focused lighting inside it, could indicate a need for more diffused and balanced illumination. This behavior could also suggest an implicit demand for lighting that supports *appearing present*—not just seeing, but being seen in a clear and non-intrusive way to ensure that their presence was recognizable to approaching buses. Lastly, dark or poorly defined areas, like the rear of the shelter, were used only briefly or for unintended purposes, leading pedestrians to avoid passing by and therefore isolating the shelter from its urban context.

Lighting distribution, brightness balance, and contrast directly influenced user positioning, therefore impacting their perception of comfort, presence recognition, and spatial awareness.

These findings support the need for lighting strategies that improve use of the space, as while users may not have been explicitly aware of how lighting shaped their behavior, their spatial decisions reflected the influence of brightness, contrast, and distribution.

3.3.4 Synthesis

The combined findings from the quantitative, qualitative, and mixed-method investigations point to critical gaps in the current lighting configuration of the bus stop, particularly in terms of spatial awareness, safety, comfort, and legibility.

From the quantitative luminance analysis, it became evident that the current lighting setup creates an unbalanced brightness hierarchy. The advertisement panel dominates the scene with excessive brightness, while ambient lighting fails to provide sufficient spatial definition. This imbalance compromises comfort and legibility, as users are left navigating unclear spatial boundaries, a product of the hash contrast between the overly bright advertisement panel and the much dimmer ambient lighting.

The qualitative interviews with pedestrians, cyclists, and a bus driver confirmed and contextualized these findings. All users expressed difficulty perceiving others at the stop and a sense of isolation or disengagement caused by poor lighting.Specifically, users called for warmer, more inviting light, improved visual communication of presence, and a lighting setup that supports recognition without glare. These insights revealed that lighting did not only affect personal comfort and interaction at the stop, but also had broader implications for how the space was mentally mapped and experienced within its urban context.The absence of coherent and context-sensitive lighting diminished users' space awareness and made the bus stop feel disconnected from its surroundings, undermining its legibility as an urban element and weakening its contribution to the user's internal image of the city.

The mixed-method speed-based legibility studies revealed that legibility requirements differ significantly depending on user speed. Drivers need a wider-angle, long-distance view to detect the presence of people at the stop, while cyclists require mid-range legibility with controlled contrast to prevent glare caused by the overly bright advertisement panel and the surrounding darker ambient lighting. The contrast between the brightly lit advertisement panel and the dim ambient surroundings contributed to visual discomfort at close range; however, both drivers and cyclist also expressed that when the vertical ad panel is appropriately lit and perceived from a distance, it can enhance the visibility of silhouettes inside the shelter and significantly improve presence recognition for approaching vehicles, thereby supporting the intersection safety. Pedestrians, on the other hand, would benefit from a clear vertical surface that helps locate the stop without causing visual obstruction when standing near it. These findings emphasize the need for a light distribution strategy that is directionally sensitive supporting legibility before arrival, while preserving comfort upon proximity, and arised the thought of backlighting as a resource for improving the perception of presence and therefore safety in the bus stop when the brightness, distribution and contrast are controlled variables.

Behavioral observations further reinforced these conclusions. Users naturally avoided areas near the ad panel due to brightness discomfort, while preferring to stand in front of or beside the shelter where light was softer and views to the street were unobstructed. The interior of the shelter was used only briefly, and the rear side was largely abandoned. These patterns suggest that current lighting unintentionally restricts spatial use, reducing both comfort and spatial awareness.

These layered insights—grounded in the core themes of perception, movement, and urban identity- highlighted the limitations of current lighting strategies and became the basis for formulating three sub-research questions, addressing the specific lighting variables—brightness, contrast, and distribution— and testing their impact in perceived comfort, safety, spatial awareness and legibility.

3.4 Research driven approach to Design

These insights led to the formulation of three sub-research questions, each one isolating a critical parameter for evaluation. Together, they operationalize the main research question—*How can a lighting strategy that responds to urban movement turn waiting time at bus stops into a safer and more visually engaging urban experience?*. Rather than proposing a single fix, the analysis highlighted that these spatial and perceptual challenges are tied to three interdependent lighting variables: brightness, contrast, and distribution/directionality.

SRQ1: How can the brightness hierarchy between the different lighting layers of the bus stop be rebuilt to improve users' spatial awareness and reduce visual discomfort at bus stops?

SRQ2: Can the use of backlighting influence the visibility of user silhouettes and enhance presence recognition from the surrounding urban environment?

SRQ3: Can a visually recognizable lighting distribution improve the identification of a bus stop at night for different types of approaching users?

Sub-Research questions

3.4.1 SRQ1: How can the brightness hierarchy between the different lighting layers of the bus stop be rebuilt to improve users' spatial awareness and reduce visual discomfort at bus stops?

The luminance analysis conducted at the Glyptoteket bus stop revealed a fragmented lighting environment defined by unbalanced brightness hierarchies, where a single vertical source (the advertisement panel) overpowered the remaining layers, disrupting the perceptual field. This configuration limited user comfort and difficulted space awareness within the shelter.

The aim of SRQ1 is to test whether rebuilding the hierarchy of luminance among the different lighting layers can improve perceived spatial awareness and visual comfort within the bus stop.

There is research linking lighting conditions in waiting areas to perceived comfort, particularly regarding brightness levels and their spatial relationships. As Hvass et al. (2021) found in their lab experiment simulating urban transport waiting areas, the perception of the difference of luminance intensities in the two light zones within the designated area influences how users experience the space. Rather than relying on absolute values, the study emphasizes the importance of brightness ratios between different zones in shaping user perception.

Scope and Limitations: Lighting Layers

To operationalize this sub-research question, it was necessary to revisit the lighting layers and reference surfaces identified in the baseline analysis and assess how modifying their configuration could influence the perceptual hierarchy within the shelter. Each lighting layer plays a distinct role in the spatial experience, yet not all are equally adjustable in practice.

The advertisement panel, which emerged as the most visually dominant element, produces an intense vertical glow that draws disproportionate attention. While its impact on the overall luminance structure is significant, this component is managed by a third-party advertising agency and therefore lies beyond the control of this project. Any effort to recalibrate its brightness falls outside the feasible design scope.

Similarly, the ambient street lighting, which provides diffuse illumination across the urban environment, is governed by Copenhagen's municipal lighting policies and sustainability targets. Modifying these fixtures would contradict the cities master plan and moreover risk disregarding or creating an unintended negative impact in other activities supported by the current layout, therefore this option was ruled out as a viable strategy.

Within these constraints, the shelter's integrated accent lighting—originally designed as ceiling-mounted spotlights—represented the only manipulatable lighting layer. The focus of this investigation, therefore, centers on how this single modifiable layer might be reconfigured to soften the luminance disparity introduced by the ad panel and contribute to a more coherent and comfortable spatial environment.

Conceptual Exploration: Transitional Luminance Planes

Given that the two dominant luminance sources—the ad panel and the streetlights—cannot be changed, a possible design strategy is to use the third light source to introduce a transitional lighting plane between them. Rather than allowing the space to shift abruptly from low ambient illumination to a highly luminous vertical panel *(Figure 18)*, rendering the focal layer of the bus stop into a middle luminance layer could help the eye adjust gradually and improve overall spatial clarity.This approach is strongly supported by the literature. Hvass et al. (2021) demonstrated that lighting schemes with smoother luminance transitions were perceived as more harmonious.

To explore the effect of smoothing the visual transition between the dim ambient street lighting and the intense glow of the advertisement panel, two conceptual strategies were visualized through Photoshop renderings. These were not intended as finalized designs but as lighting gestures to assess whether introducing an intermediary transition plane—either horizontal or vertical—could soften the sharp luminance jump between the ambient street lighting and the advertisement panel.

Figure 18.Current lighting setup.

Strategy A: Horizontal Transition Plane

This first concept explored the idea of creating a transitional brightness layer on the ground, increasing the luminance of the shelter floor area to form a gradient between the darker exterior and the vertical glow of the advertisement panel *(Figure 19)*. The intention was to reestablish the standing zone as a perceptual anchor, giving visual weight to the user's position and guiding the eye upward with less contrast shock.

The positive insight of this strategy lies in its clarity defining the space physical boundaries, which could reinforce space awareness. However, the rendering also exposes potential challenges. The strategy remains mostly two-dimensional, lacking depth or vertical engagement. If executed with actual lighting, the solution risks introducing glare for it would require a shift in the lumen output of the fixtures. Additionally, without supporting light on surrounding vertical elements, the ad panel still dominates, making the space feel flat.

This concept was tested by intensifying the existing spotlights aimed at the bench and floor. The simulation showed an increase in horizontal illuminance (~220 lx on the floor, ~152 lx on the bench). However, luminance maps revealed uncomfortable brightness levels on vertical surfaces, creating harsh contrast and visual glare. Despite achieving a technically improved brightness ratio (sidewalk : bench : panel ≈ 1:5:8), the perceptual experience remained uncomfortable and unbalanced. The floor was overlit, and the shelter's internal spatial coherence was not restored.

Figure 19. Transition horizontal plane.

Strategy B: Vertical Transition Plane

The second concept introduced a softly illuminated plane, activating the vertical back glass panels of the shelter *(Figure 20)*. This light layer behind the bench was intended to act as a luminance transition , providing spatial enclosure and guiding the eye with a more gradual brightness shift from rear to front. Rather than grounding the user, this strategy focused on anchoring them within the spatial volume of the shelter.

This approach revealed several promising design potentials. The vertical backlight created a clear spatial boundary, improving depth perception and internal cohesion. It distributed attention more evenly across the interior surfaces—without directly competing with the ad panel. However, it also presented critical considerations. If the brightness is too subtle, the effect may go unnoticed; if too intense, it may introduce new visual conflict or reflection issues on the shelter's rear glass. Additionally, it provides less functional lighting for the bench, meaning that while the spatial perception is improved, the usability of the bench may remain limited if not paired with additional solutions or careful design.

This strategy was approximated by redirecting the spotlight output into a concealed linear light element along the shelter's rear wall. The simulation achieved an even spread of ~75–85 lx across the back surface. The luminance distribution was softer and more balanced, creating a perceptual gradient that supported enclosure without glare. Compared to the intensified spotlight configuration, this solution offered significantly greater visual comfort and spatial clarity, making it the most successful strategy tested.

plane—focused on the ground or bench area—helps clearly define spatial boundaries without impeding the visual engagement with the surroundings, which could be positive towards space awareness. Together, these strategies suggest that transitional luminance is not a singular solution, but a design approach that can be calibrated to prioritize different perceptual needs depending on the context and user focus.

Figure 20. Transition vertical plane.

These conceptual explorations confirmed that introducing a transitional luminance plane is a promising strategy for rebalancing the visual hierarchy within the bus stop. While both the horizontal and vertical approaches aim to mediate the contrast between the streetlights and the advertisement panel, each offers distinct spatial and perceptual benefits. A vertical plane—by softly illuminating the rear surface—emphasizes spatial depth and can help make the shelter feel more three-dimensional. It may also enhance visual comfort from within, creating a subtle ambient glow that compensates for the ad panel's intensity.

3.4.2 Sub-Research Question #2: Can the use of backlighting influence the visibility of user silhouettes and enhance presence recognition from the surrounding urban environment?

One of the recurring issues identified through both interviews and on-site observations was the difficulty in recognizing whether someone was waiting inside the bus shelter. Poor legibility of the presence of users, particularly at night, generated concern with functional clarity and perceived safety. Drivers, for example, pointed out that unless a person was standing along the front of the shelter and actively signaling, it was often hard to tell if the stop was occupied. Cyclists also said they could only see movement at the last possible second, potentially compromising reaction time and comfort.

To address this problem, SRQ2 outlines the use of backlighting as a method to enhance presence recognition. The concept of backlighting was selected for its ability to highlight silhouettes without creating excessive brightness This approach is supported by previous findings in perceptual lighting research. Hvass et al. (2021) demonstrate that when the contrast between a lit object and its background increases, the object becomes more distinguishable and draws more attention. Their study found that “the perceived quality of an object in a space is affected by the light level on the object seen in relation to the light pattern in the background,” confirming the visual impact of background illumination strategies like backlighting (Hvass et al., 2021, p. 9).

By placing an area light source behind the bench area of the shelter, the proposal aimed to enhance visual contrast between the human figure and the background surfaces. The strategy was based on the following hypothesis: A lit background behind a person increases the recognition of their presence inside the shelter. One of the key goals of this approach is to enhance legibility for the external users without subjecting the interior users to direct lighting, preserving comfort while ensuring presence recognition.

To test this lighting design intervention, two visual simulations were created using Twinmotion and Adobe Photoshop. *Figure 21* shows the current lighting condition, where illumination primarily comes from overhead street lighting, an internally lit advertisement panel and two direct spotlights. *Figure 22* illustrates the same shelter but with the addition of a backlit plane behind the bench. The simulated backlighting is neutral in tone, designed to softly illuminate the vertical surface of the shelter allowing seated or standing figures to appear as readable silhouettes when viewed from the front or side.

A total of 26 participants took part in a visual survey to evaluate the impact of this design implementation. Respondents were design students, regular commuters, and urban dwellers who were asked one question: "In which of these two photos can you more easily tell if someone is waiting at the bus stop?" The results showed a clear preference for the backlit configuration. 23 out of 26 participants, or 88.5%, perceived *Figure 22* with the use of backlighting as more effective in conveying user presence, while 11.5% (3) perceived no difference or preferred the existing condition.

The responses confirmed that backlighting notably improves the contrast ratio around the figure, making human presence more readable from a distance. The increased contrast between the lit background and the unlit or less-lit figure helps outline the silhouette more clearly, addressing a key concern raised during the interviews and observations.

In addition to improved silhouette recognition, the survey results suggest a broader implication for how lighting can communicate occupancy without requiring users to take actions, such as stepping forward or waving. The presence of a visible figure naturally informs both drivers and other road users of human activity at the stop, potentially reducing hesitation, or accidents. This is particularly important on busy routes where easy recognition from afar supports smoother transport operations.

As a result, this sub-research question helped validate backlighting as a simple and effective lighting tool for improving presence recognition and therefore perceived safety in bus stops. The positive feedback from participants supports its further development in the final design strategy. As a spatial cue that enhances silhouette contrast and communicates occupancy at a glance, backlighting serves as a functional solution and a perceptual enhancement to the shelter's role in the urban nightscape.

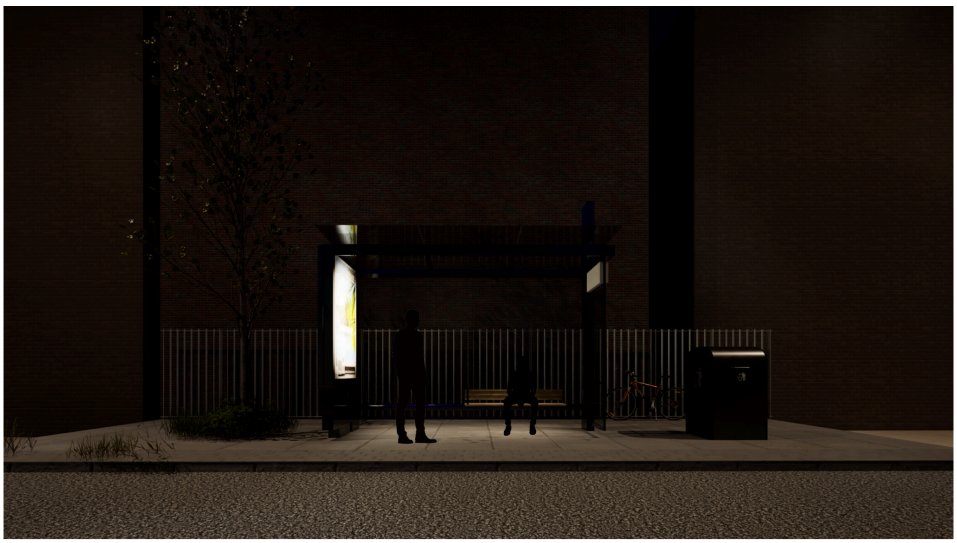


Figure 21. Bus stop with existing lighting conditions

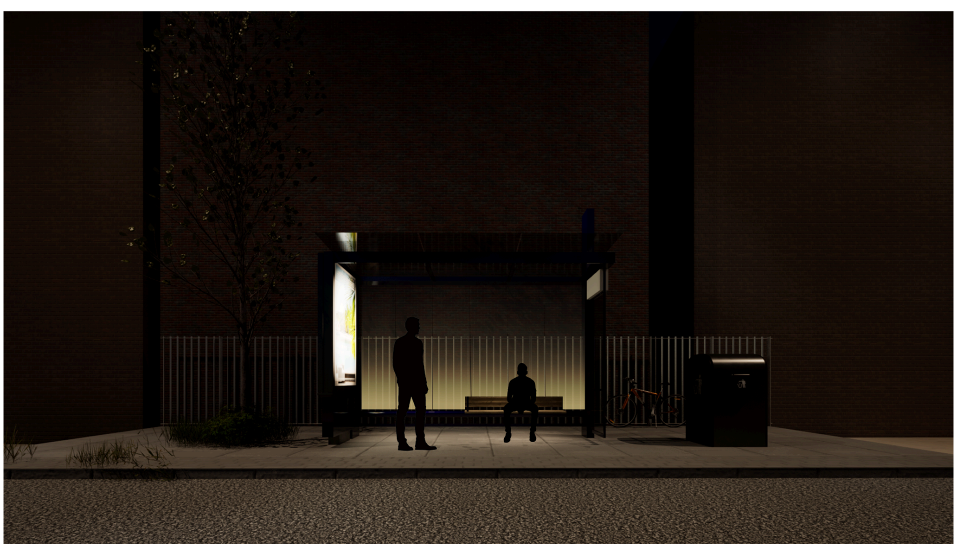


Figure 22. Bus stop with backlighting

3.4.3 Sub-Research Question #3: Can a visually recognizable lighting distribution improve the identification of a bus stop at night for different types of approaching users?

To address the legibility challenges of the bus stops addressed through interviews and motion-based visibility studies, SRQ3 investigates how a vertically-oriented lighting distribution can support bus stop recognition from a certain distance and different approaching angles. The proposal aims to create a rhythm of light behind the shelter structure, allowing users—whether walking, cycling, or driving—to more easily locate the stop during nighttime conditions.

The choice of vertical lighting elements was informed by recommended practices highlighting the importance of lighting vertical surfaces to enhance legibility. According to the American Public Transportation Association (2020), horizontal lighting alone is insufficient for recognizing upright objects like people, signage, or structures. Lighting that targets vertical planes plays a more effective role in supporting recognition in low-light urban environments.

For this test, a comparative visual simulation was conducted using six rendered images developed in Twinmotion and edited in Adobe Photoshop. The images were created from three distinct user perspectives: the pedestrian viewpoint simulated the sidewalk approach; the cyclist view was taken from the bike lane adjacent to the street; and the bus driver's perspective captured the road view while approaching the stop. For each of these three angles, participants were shown two images: one representing the existing nighttime condition and another showing the same scene with three slim vertical lighting panels added behind the shelter. These illuminated panels were designed to introduce a clear and consistent lighting rhythm, enhancing the bus stop's visual identity and making it more legible from different approaching angles.

Participants were asked two questions. First: "In which of these two images can you recognize the bus stop more clearly?" This allowed for a direct evaluation of the legibility improvement. Second: "If this lighting solution were implemented at multiple bus stops in the city, do you think it would help you recognize or remember the stops more easily?" This additional question was aimed at assessing whether the proposed lighting rhythm could contribute to a broader perception of continuity and spatial memory across the city. By combining questions focused on both functional clarity and cognitive mapping, the test sought to explore the potential of vertical lighting as a practical intervention and as a contributor to urban identity on a micro scale.

A total of 26 participants took part in the survey. Responses were analyzed by user perspective to assess how different approach angles influenced the recognition of the bus stop. In the driver's view (simulated from the road while approaching the stop) 22 out of 26 participants (84.6%) indicated that the version with vertical lighting panels was more recognizable than the current condition. In the cyclist scenario (viewed from the bike lane at an intermediate angle) 20 of 26 respondents (76.9%) also selected the version with vertical illumination.

By contrast, the results from the pedestrian perspective (rendered from the sidewalk at close range) were more evenly split. Only 12 participants (46.2%) stated that the lit version made the stop easier to recognize, while 14 participants (53.8%) reported no significant difference. This was attributed to the simulated angle, where the lighting panels were less visually prominent or partially blocked from view.

In addition to asking which version improved recognition, the survey included a second question: “If this lighting solution were implemented at multiple bus stops in the city, do you think it would help you recognize or remember the stops more easily?” Out of 26 participants, 20 (76.9%) responded positively. These respondents indicated that seeing the same vertical lighting element repeated across various stops would help them form stronger mental associations and recognize the stops more easily, especially at night. This feedback reinforces the notion that vertical lighting can operate as a legibility tool and as a component of a broader perceptual rhythm within the city.

Together, these findings support the value of vertical illumination as a layered design strategy. While its spatial effectiveness may vary depending on the user angle, its impact on nighttime legibility and the image of the city is evident for the majority of the users. The sub-research question confirms the inclusion of this element in the final design, can improve recognition from a distance and also to support the construction of urban identity through micro-scale repetition.

Figure 23. Bus stop from approaching pedestrian view

Figure 24. Bus stop from approaching pedestrian view with vertical lighting

Figure 25. Bus stop from approaching cyclist view

Figure 26. Bus stop from approaching cyclist view with vertical lighting

Figure 27. Bus stop from approaching bus driver view

Figure 28. Bus stop from approaching bus driver view with vertical lighting

CHAPTER IV: RESULTS

4. Results

This chapter presents the outcome of the research- design process. The results propose a redesign strategy for bus stops developed through key parameters and associated perceptual qualities. In order to do so, these results present a lighting design proposal that offers a possible conceptual solution to reposition the Glyptotek (Line 2A) bus stop as an active and engaging element within the urban fabric of Copenhagen. The following sections explain how the core design concept was translated into a layered lighting strategy, developing its integration and technical detailing.

4.1 Concept

Drawing on the idea of "A designed moment", the conception of the project reimagines the bus stop as a temporary aperture in the nightscape: something to be noticed, understood in context, and retained in memory.revealing

The design concept of the proposal has its origin in the act of *revealing*. In this context, *revealing* is about cultivating a sense of something about to happen as one approaches. The bus stop, often overlooked in the daily flow of the city, is treated not as a leftover space but as a moment worth noticing. The design reframes it as a meaningful pause that carries significance as an in-between place for those who wait and those who pass by.

Crucially, *revealin*g is tied to movement. The bus stop becomes visible not all at once, but gradually—unfolding as one approaches, adapting to different paths. Light guides this encounter, shaping a layered perception that evolves with proximity. In doing so, it communicates its function and presence dynamically, echoing the pace and direction of urban flows. This motion aware quality takes the stop from a static object to an active participant in the image of the city, making it a contributor to the urban identit*y* of Copenhagen.

Figure 29. Final render from front view

Figure 30. Final render from side view

4.2 Design Strategy

The strategy of this design is developed in response to the sub-research questions and grounded in the theoretical and analytical framework built during the exploration of this thesis. Therefore, this design is based on the blocks of perception, movement, and identity. Each design element is tied to a specific lighting parameter—brightness, contrast, and distribution—and engages with distinct perceptual qualities such as comfort, space awareness, perceived safety, and legibility.

The following sections present this strategy through three design layers built upon the foundation blocks—*Atmosphere and Presence*, *Rhythm*, and *Image of the City*.

4.2.1 Atmosphere and Presence

Atmosphere is not added to a space; it grows from it. During the observations at Glyptoteket, it became clear that people do not wait just anywhere. They choose certain spots—slightly set back, softly lit, not exposed. These choices, often unconscious, confirm how light supports comfort and orientation in everyday situations. This understanding is supported by the perception block of the literature, where authors like Hvass et al. (2021) and Amoruso et al. (2022) describe how balanced luminance makes it easier to understand space, and to feel at ease within it. These authors also support the inclusion of

In response, the project introduces an ambient plane—a vertical surface that offers a focal layer of light across the interior of the bus shelter. It is placed between the advertisement panel and the surrounding darkness, acting as a transition. This surface is not meant to highlight but to bring balance.

The ambient plane is informed through the exploration in the Sub-Research Question 1 and works with the lighting parameter of brightness,but avoids strong levels. Instead, it maintains a gentle relationship between lit surfaces balancing the luminance levels. In doing so, it supports two essential qualities:
– Comfort, by reducing visual stress.
– Space awareness, by letting the form of the shelter become quietly understandable.

The ambient plane does not try to draw attention. It tries to support the act of being present by providing the exterior image of the shelter with a backlighting scene where the different users perform ephemerally.

Presence in this proposal is understood as feeling seen but not observed. The literature speaks in the Perception block where authors such as Amoruso et al. (2022) and Hvass & Hansen (2022) describe how contrast helps define the human figure in low-light situations. Presence recognition does not come from brightness alone, but from relationships between background and body.

This gesture is tied to the lighting parameter of contrast, and supports the perceptual quality of perceived safety through presence recognition. It supports perceived safety, not by surveillance or exposure, but by letting others know that someone is there—and letting the person waiting feel that they are part of the space, not hidden from it. It allows people inside the stop to feel acknowledged without being overexposed and helps bus drivers or others at a distance detect the stop’s occupation.

This element addresses Sub-Research Question 2, which examined how lighting can support human recognition at night and reduce feelings of insecurity.

Together in the ambient plane, *atmosphere* and *presence* form the perceptual foundation of the bus stop experience and allow waiting to become an act of quiet belonging. One shapes how the space is felt from within; the other shapes how it is understood from outside. Both rely not on intensity, but on balance—on the ratio calibration of brightness and contrast with the surrounding context to support comfort, space awareness and perceived safety.

4.2.3 Rhythm

The notion of *rhythm* emerges from the movement block of the literature review, where lighting distribution is understood as a tool to support legibility during approach (Navarro et al., 2011; Hvass et al., 2021). In this proposal, that idea is materialized through the use of vertical rhythm panels—slim, repeated lighting elements positioned within the ambient planeat the ack of the shelter and oriented along the direction of traffic flow.

These panels are tied to the lighting parameter of distribution, with an emphasis on its directional quality. Their primary role is to support the perceptual quality of legibility, making the stop easier to identify from a distance—especially for users in motion, whether walking, cycling, or driving.

This strategy directly addresses Sub-Research Question 3, which investigated whether a recognizable lighting pattern could improve the identification of bus stops at night for users approaching at different speeds. The aim is to create a form of urban lighting that aligns with the rhythms of movement, offering cues that are both functional and perceptual.

By shaping light in response to speed, direction, and context, the design allows the stop to become part of the city’s tempo through a layered sequence of light embedded within the collective nighttime image of Copenhagen.

4.2.4 Image of the City

In the urban identity block, authors such as Ebbensgaard (2015) and Lynch (1960) describe how cities at night gain their identity not from singular landmarks, but from repeated, recognizable cues—details that accumulate into a shared spatial memory. This proposal contributes to that memory through the combined action of the three lighting strategies.

Together, the ambient, backlighting, and rhythm planes form a lighting system that supports comfort, perceived safety, space awareness and legibility.

4.3 Design Features & Dimensions

This section outlines the physical and technical characteristics of the final lighting design intervention, focusing on its material composition, spatial configuration, and integration with the existing shelter structure. All key components, including panel thickness, depth, spacing, and supporting structure, are described in relation to both function and user perception. Visual references, such as the annotated section drawing *(Figure 32)* and exploded axonometric view *(Figure 31)*, accompany the explanation to clarify the assembly logic and spatial impact of the intervention.

The existing bus stop structure (primarily composed of glass panels and painted metal frames) has an overall depth of approximately 1.60 meters, a total height of 2.65 meters and width of 3.80 meters with the seating plane positioned at 0.40 meters. These measurements frame the spatial limits within which the new lighting features have been inserted..

The exploded axonometric drawing *(Figure 31)* illustrates the layered composition of the lighting intervention and how it integrates with the existing bus stop structure. Each numbered element corresponds to a specific material or component that contributes to the overall lighting system.

Component 1 represents the added glass layer. This sheet closes the system from the rear, working in tandem with the existing bus stop glazing (Component 4) to sandwich the vertical panels in place. The added transparency ensures that the rear of the shelter remains visually permeable when viewed frontally, preserving the openness of the original design.

Component 2 is a custom-designed metal frame that supports and attaches the lighting system to the back of the bus stop. This structural element is dimensionally aligned with the existing metal elements of the shelter to maintain visual coherence. The frame extends the shelter depth by 11 cm and discreetly houses a recessed linear light source. This fixture emits an upward-facing, uniform wash of light that grazes the vertical panels, producing a soft gradient effect that shifts depending on the viewer's motion and angle of approach.

Component 3 consists of the vertical metal panels, which are the primary visual elements of the intervention. These panels are 1 cm thick, 10 cm deep, and spaced 5 cm apart. While the panels themselves do not emit light, they reflect the light from the recessed linear source, creating a glowing effect when seen from oblique angles. This rhythm of repetition is especially perceptible from the side (such as when approaching by bike or bus) forming a lit surface that backlights occupants within the shelter. When viewed frontally, however, the 1 cm panel thickness and consistent spacing allow the back side of the shelter to remain mostly transparent, ensuring that the intervention does not compromise the transparency of the shelter.

Component 4 refers to the original glass surface at the back of the bus stop. This was retained as part of the design to minimize alteration to the existing structure and to utilize its light-transmitting qualities.

Component 5 is the bus stop structure itself, onto which the entire system is mounted.

The exploded view communicates how each layer contributes to the performance of the lighting intervention. It highlights the importance of integrating new components in a way that respects the architectural identity of the shelter while introducing a clearly perceptible lighting cue that varies by angle and movement.

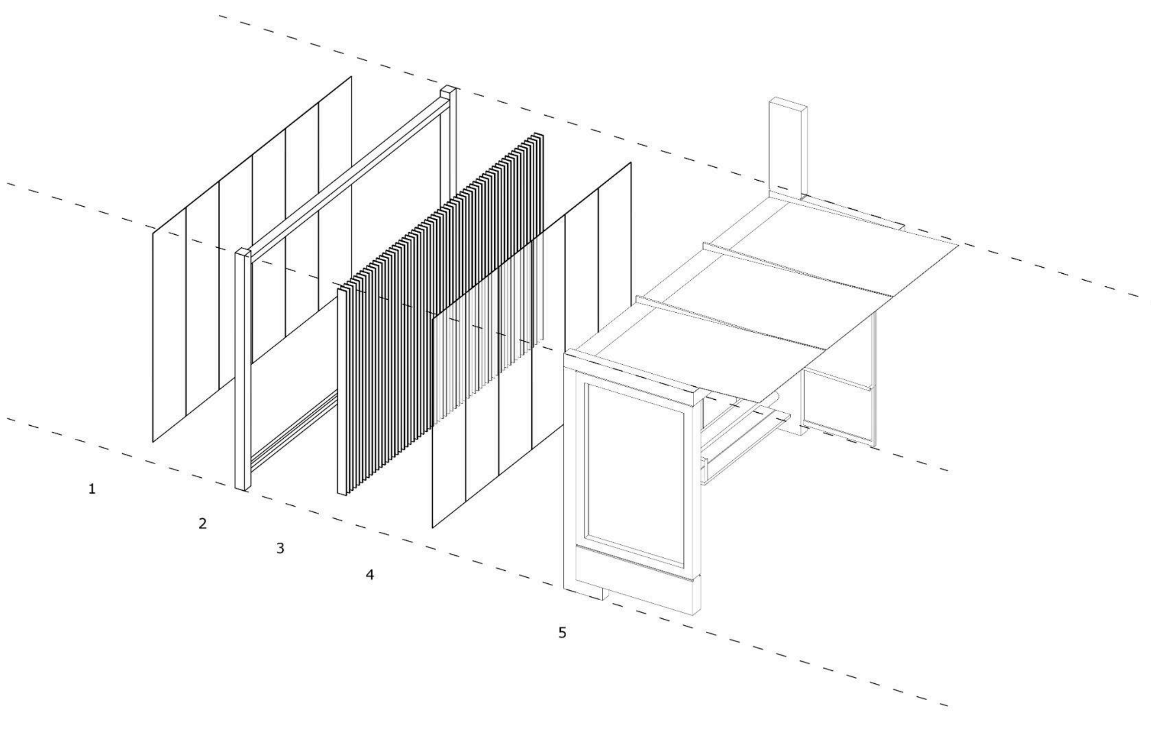


Figure 31. Isometric exploded view

The sectional drawing *(Figure 32)* offers a precise cross-sectional view of how the lighting intervention physically interfaces with the existing bus stop structure. Where the exploded axonometric emphasizes the layering of materials, the section focuses on the connection logic, and structural elements involved in the integration.

Seen in profile, the newly added metal frame is anchored directly to the horizontal bottom edge of the original shelter structure. This anchoring point demonstrates how the system is dimensionally aligned with the existing elements to avoid disrupting the visual and structural rhythm of the shelter. The frame's geometry mirrors the shelter's structural profiles, allowing for seamless extension of the form by 11 cm.

Within this extended cavity, the vertical panels sit securely in a slot defined by the new frame. Their 10 cm depth is evident in the drawing, projecting outward from the shelter's rear plane, but carefully limited to maintain spatial compactness on the sidewalk side. The linear light fixture is integrated into the base of the frame and fully recessed to conceal the source and avoid direct glare.

The additional glass sheet appears in the section as a discrete boundary enclosing the entire rear cavity. Its positioning just beyond the panel depth maintains a clean finish while sealing the lighting system from environmental exposure. This protective layer also supports the visual continuity of the shelter, maintaining its transparent character when viewed from frontal positions.

The section clarifies how the entire lighting intervention is mechanically and visually subordinated to the existing shelter framework. No structural elements pierce or override the shelter; instead, they attach onto existing connection points and mirror the bus stop's material language. The drawing shows how the design aims to remain both additive and respectful, while introducing new functionality through lighting without compromising the form or transparency of the original architecture.

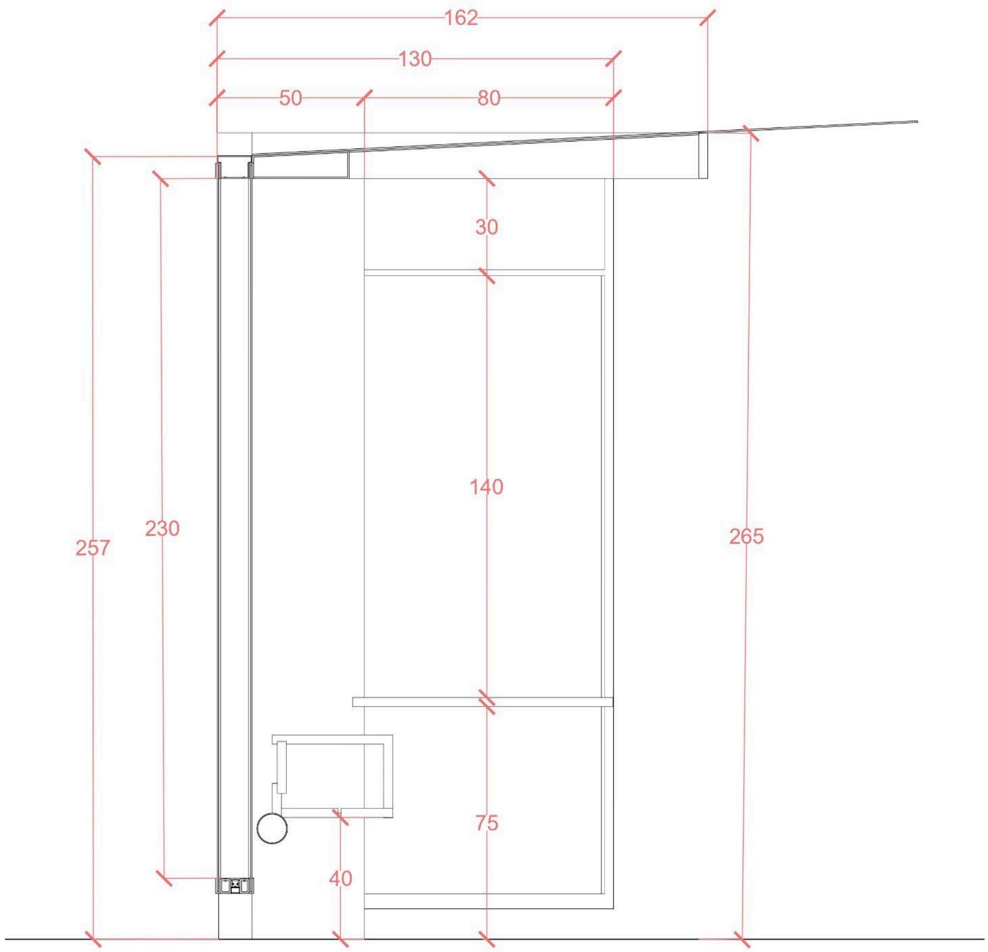


Figure 32. Section

Together, the exploded view and the section drawing communicate how each component contributes to the overall integration of the lighting intervention. While the exploded view illustrates the layered assembly and interaction of materials, the section drawing clarifies how the system connects mechanically to the existing shelter without altering its core structure. Both focus on emphasizing the importance of an additive and respectful design approach, introducing a visually perceptible lighting cue that varies by angle and movement, while preserving the architectural identity, transparency, and material continuity of the original bus stop.

Calibrated simulations

To evaluate the spatial and perceptual effectiveness of the final design, a series of DIALux simulations were conducted focusing on both illuminance (lx) and luminance (cd/m²) levels across relevant zones: the bench, the floor inside the shelter, the user's face, the advertisement panel, the nearby street surface, and upward-facing reflective surfaces. These results were compared with earlier tests developed during the concept phase to assess how the final design performs in terms of brightness balance, visual comfort, presence recognition, and legibility in motion.

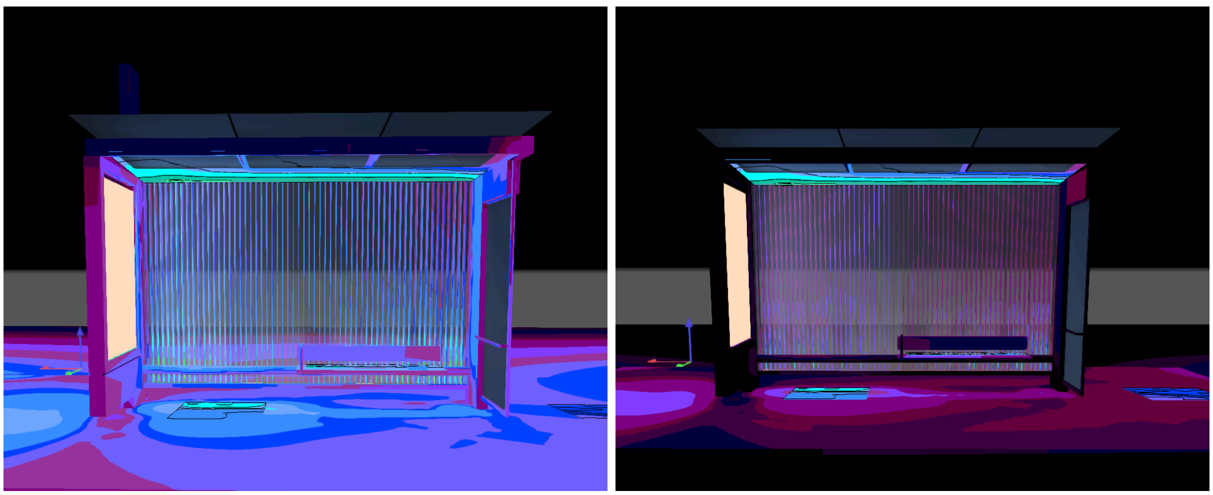


Figure 33: Simulation Illuminance and Luminance mapping.

The final design demonstrates a layered lighting environment that meets many of the project's intended goals:

Brightness and comfort (Sub-RQ1): The measured values at the bench (25.5 lx) and on the floor (22.5 lx) fall within a moderate range that avoids both overexposure and under-illumination. These levels, when paired with a luminance ratio that preserves contrast with surrounding elements, help produce a calm interior with sufficient spatial clarity supporting boundary definition without impeding space awareness. Compared to earlier fixed-point light tests—which showed uneven and abrupt lighting transitions—the focal plane in the final proposal distributes light more uniformly, contributing to a more comfortable environment that supports space awareness.

Presence and perceived safety (Sub-RQ2): The soft luminance behind the seated area allows people to be visible as silhouettes without being exposed to harsh light. The face illuminance value (5.65 lx) remains low but works in combination with the backlighting (contrast) to make presence noticeable without being confrontational. This aligns with the intention of creating a sense of feeling seen but not observed. It avoids surveillance-like lighting strategies in favor of subtler cues that still communicate activity at the stop.

Distribution and recognition in motion (Sub-RQ3): The vertical rhythm panels, indirected lit by an upward-facing source follow a decreasing luminance gradient as they reach the top of the bus stop (max:10 - min:1 cd/sqm), The panels generate a layered glow within the focal plane that becomes more legible from moving viewpoints. From lateral approaches—such as from a cyclist or a bus driver's angle—the panels produce a dynamic rhythm. From within the shelter, however, they remain nearly invisible, preserving the atmosphere. This strategy succeeds in distinguishing the stop at night through directionally oriented light cues, supporting legibility from a distance without visual noise.

Further reflections

While the simulations confirm that the design supports comfort, presence, and recognition through subtle layering, several limitations must be acknowledged:

Low vertical face illuminance (5.65 lx) might not be sufficient in some real-world contexts—particularly for CCTV clarity, reading maps, or interacting with others. While it fulfills the project's aim of perceptual presence over surveillance, it may require adjustment in areas with higher safety or accessibility requirements.

Backlighting as the main strategy for presence recognition relies on silhouette visibility, which may become less effective in poor weather (rain, fog) or in cluttered urban environments. There is a risk that presence might not register clearly unless the contrast conditions are optimal.

The design intentionally avoids high general brightness, which is a strength in terms of subtlety and comfort, but could become a challenge in more brightly lit urban surroundings. In areas with strong ambient lighting (e.g. near commercial facades), the soft gradients and rhythms introduced here may be visually overpowered, reducing their perceptual impact.

The legibility of the rhythm panels is highly dependent on the user's motion. While this successfully engages with movement as a perceptual trigger, it offers little to static observers from the front or sidewalk. This asymmetry raises questions about the balance between dynamic legibility and stationary clarity.

The DIALux simulations confirm that the final lighting design supports the project's conceptual framework of *revealing*, offering a refined balance between light and shadow, visibility and subtlety. It performs well in terms of human perception and spatial quality, especially for users in motion or seated within the shelter. However, the limitations discussed above point to the need for contextual calibration and further testing under varied urban conditions. In this way, the design is both a resolved proposal and an open prototype—a strategy that could be adapted, extended, and scaled to reflect the lighting needs of bus stops within the shelter typology in the city of Copenhagen.

CHAPTER V: DISCUSSION

5. Discussion

5.1 Reflections on the Role of Lighting in Narrative Placemaking

The project demonstrates that lighting can do more than provide visibility; it can support a narrative structure in urban space. By framing the bus stop as a sequence of perceptual moments—approaching, passing, and waiting—the design gives form to otherwise overlooked experiences. Lighting becomes a tool for placemaking when it reveals presence, defines space, and aligns with how people move through and emotionally interpret their surroundings. This reframing reinforces the bus stop's role not only as a transit point, but as a contributor to the nighttime rhythm and identity of the city.

5.2 User-Centered Design

The final lighting proposal responds to three distinct user profiles—pedestrians, cyclists, and bus drivers—each of whom engages with the bus stop at a different speed, angle, and level of interaction. These user types were identified early in the research and consistently guided the design's spatial and perceptual priorities. Through both fieldwork and visual testing, the lighting strategies were evaluated to ensure they support the specific needs of each group.

Pedestrian

Pedestrians interact most directly with the stop, often waiting or passing by at close range. For them, comfort and clarity within the shelter are essential. The proposal addresses this by introducing a soft ambient plane that balances the brightness inside the shelter and reduces visual discomfort caused by the unbalanced brightness hierarchy. A gently indirect lit surface behind the bench helps define spatial boundaries without glare, improving space awareness and creating a more balanced interior. The rhythm panels, while primarily visible to others in motion, produce a subtle glow that adds visual anchoring without intruding on the pedestrian's immediate field of view given their directionality. Together, these elements create an atmosphere that supports the act of waiting as a moment of quiet belonging.

Cyclist

Cyclists pass the bus stop at moderate speed and at close proximity. For this user, safety depends on avoiding sudden visual changes while maintaining legibility of the space. The proposal, although is not one of the discussed parameters, indirectly reduces glare through design by avoiding exposed fixtures and using diffused, directionally distributed lighting behind the shelter. The vertical rhythm panels, aligned with the direction of travel, become perceptible as glowing cues that signal the stop's location. These help cyclists anticipate the space in advance and react appropriately to any potential interaction, such as passengers stepping out.

The lighting strategy thus enhances both recognition and reaction time, improving safety for moving users without disrupting the overall visual field.

Bus Driver

Drivers approach the stop at high speed and need to identify both the stop and the presence of waiting passengers from a distance. For them, quick and easy legibility of the space is critical. The proposal supports this through layered vertical lighting at the rear of the shelter, creating a clear silhouette effect when someone is inside. This increases presence recognition without requiring bright frontal lighting. The rhythm panels also contribute to the stop's perception as a structure, distinguishing it from nearby ad panels or urban clutter. By enabling both legibility of the space and human presence detection from afar, the design improves driver response time and reinforces the stop's role as an active point in the city's nighttime rhythm.

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5.3 Impact of the Research Based Design Process on the Final Proposal

The use of a sub-research question in design framework allowed for a focused approach to different aspects of the lighting design. By isolating key variables—brightness, contrast, and distribution (directionality) —the research was able to asses and manipulate their individual impact on comfort, safety, legibility, and space awareness. This structure ensured that the final design proposal was not based on intuition alone but grounded in reference, analysis, and measurable lighting principles. The modular process also made it possible to adapt or scale elements of the strategy for other urban contexts.

The SRQ1 focused the research on the variable of brightness, gathering information about possible strategies to improve the hierarchy balance of the current situation. This exploration suggested the vertical transition plane, which effectively softens the experience of waiting by lowering the hash existing contrast. This strategy also raises questions about how passive lighting might influence behavior. The need to balance being in a place with being seen in a place led to the SRQ2. The use of silhouette lighting as a means of presence is effective, yet it relies on subtle visual perception which may be affected by environmental conditions such as fog, rain, or light pollution. The directionality of the light provides a way of being seen yet keeping anonymity to avoid the feeling of exposure so the user can participate in the imaginary of the city without compromising their privacy. However, this could also affect other aspects of perceived safety as face recognition at close range, compromising the feeling of safety. Further work is necessary to assess the optimus contrast ratio between user and backlighting plane that allows both silhouette recognition from outside the shelter and a clear face recognition when standing next to another user inside the shelter.

Lastly, the SRQ3 informed the design in relation to movement which translated into implementing the rhythm panels oriented toward the street to create a dynamic interaction with motion—yet this interaction is asymmetrical. Users inside the stop perceive only a faint glow from the panels, meaning the rhythm is only legible from outside (in motion) allowing the static users inside the shelter that moment of pause. This strategy proved effective when tested through visual prompts, however further testing in motion would be more suitable to better assess the effectiveness of the vertical panel rhythm throughout a city promenade verifying not only its individual impact but the overall effect when implemented at an urban scale.

As a final reflection, the SRQ impulses the stop does not aim to stand out as a destination, but rather to belong—to participate quietly in the city's nighttime image. By anchoring its presence in perception and rhythm rather than scale, the stop aligns itself with the everyday patterns that shape urban identity—not by dominating them, but by echoing them.

5.4 Standards and Benchmarks assessment

To evaluate the performance of the proposed lighting design, the results from DIALux simulations (Chapter 4) are compared against established standards and guidelines for exterior public lighting. The benchmarks used in this assessment are primarily drawn from EN 13201-2:2015, CIE 115:2023, and EN 12464-2:2014, with additional input from UITP guidelines for transit infrastructure *(Appendix I.)*

Illuminance Levels and Uniformity

The horizontal illuminance on the floor of the shelter measured an average of 22.5 lux, which exceeds the recommended 5–15 lux range for waiting areas. While the space is not classified as a circulation zone, achieving slightly elevated values is justified here, as the increase reinforces spatial clarity and contrast with the adjacent street environment. Additionally, the uniformity (U_0) of the floor was found to be sufficiently even based on the luminance visual output, although not formally measured in this research . A benchmark of $U_0 \geq 0.4$ would be desirable for reinforcing spatial boundaries, but is not mandatory for this context.

For vertical illuminance, especially at 1.5 m height (approximating face level), the design fulfills the recommended range of 2–10 lux (CIE 115:2023) both in front of the ad panel and facing the bench. Although the perceived safety in this research is based on the presence recognition through the silhouette, this level indicates the existence of basic facial recognition according to the standard , particularly at close range through the softly lit backlighting plane. However, further studies should be conducted taking into account the contrast ratios generated within the shelter to assure that this is met.

Glare Control: UGR and TI

Although glare was not a central variable in this study, the design was developed to avoid direct light sources and minimize discomfort. According to EN 12464-2:2014, the UGR (Unified Glare Rating) for semi-enclosed outdoor shelters should ideally remain below 22, with a preferred value under 19. While this was not simulated in DIALux, the use of recessed and indirect lighting elements that substitute the former visible direct spotlights should improve the glaring rating following design principles. This suggests that in the proposal the glare caused by the intervention is likely within acceptable limits for users standing inside the shelter.

For users approaching the stop, particularly cyclists and drivers, a Threshold Increment (TI) value would be more relevant to evaluate glare along the line of approach. According to EN 13201, a TI ≤ 15% is considered acceptable. Future work could include TI simulations to more precisely assess approach comfort and visibility.

Spectral Quality: CRI and CCT

The Color Rendering Index (CRI) in the proposed lighting design is assumed to meet or exceed CRI ≥ 80, which is preferred for human-centered environments. This aligns with CIE 115:2023 recommendations for public spaces with pedestrian presence.

Regarding Correlated Color Temperature (CCT), no fixed value was applied in the current proposal. A warm white (around 3000K) is recommended in UITP guidelines for creating inviting environments, but this remains open for future testing. Further studies could explore how cooler or warmer tones—or even colored light (e.g., red or blue)—may influence the perception of time, atmosphere, or emotional response during waiting.

Overall, the proposed lighting design meets or exceeds the most relevant benchmark values for horizontal and vertical illuminance, visual comfort, and perceptual clarity. While glare values (UGR and TI) were not formally calculated, the design choices suggest that both user-facing and movement-based comfort are supported. Further simulation and on-site prototyping could validate these findings more precisely.

5.5 Scalability & Implementation

The physical module developed in this thesis has been designed in direct response to the dimensions and structure of the standard bus shelter used across Line 2A in Copenhagen, and the numerical outcome is context specific to the case study bus stop. As such, it can be implemented across other shelter stops in the city that follow the same typology and structural configuration as the Glyptoteket stop. The system was developed to integrate with the existing metal frame and glazing elements, making it easily attachable and minimally invasive. However, adapting the module to other types of stops that vary in some dimensions would require further design development and contextual testing to ensure the correct fitting.

While this thesis does not study the direct implementation of the final design across different locations, the lighting strategy itself—particularly its core principles—offers a transferable framework that could be adapted to other contexts. The concept of the *focal plane*, which combines the ambient light plane, backlighting plane, and vertical rhythm panels, provides a flexible structure that could be tested and modified for use in other bus shelter typologies.

For shelters with different configurations, these elements could be reinterpreted according to form, material, or orientation—maintaining the perceptual goals of comfort, presence recognition

, space awareness and legibility. In cases where there is no shelter infrastructure at all, the most relevant transferable aspect is the strategic approach to movement. Recognizing movement as a key user feature in public space offers a valuable lens for future design work, allowing microscale lighting interventions to be contemplated within the rhythm of a broader urban context.

In this way, while the final design remains specific to the Glyptoteket stop, the underlying strategy presents a broader design methodology—one that could inform context-sensitive lighting solutions in other parts of the city or in similar transitional spaces.

5.6 Limitations

While this thesis presents a thorough exploration of how lighting can reframe the bus stop experience in the urban context through a movement- and perception-sensitive design strategy, it is important to acknowledge the limitations that define depth, and applicability of the work. These limitations span from the selection of methods to the technical resolution of the proposal and the transferability of results. They are discussed as transparent boundaries within which the research was conducted and decisions were made.

5.6.1 Methodological Scope

User testing and in-situ evaluation were beyond the scope of this project due to time and resource constraints. As a result, behavioral insights rely on non-intrusive observations and survey-based perception testing, which, while useful, cannot fully replace long-term ethnographic or participatory methods. The behavioral mapping at Glyptoteket offers only a partial view into broader patterns of use. While it revealed clear spatial preferences and lighting-related behavior, the study is limited in duration and cannot fully capture seasonal, temporal, or social variations.

The visual perception survey used for SRQ3 was carried out using still image comparisons generated from simulations in Twinmotion. While these provide helpful visualizations into how added lighting layers affect recognition from different angles and speeds can influence the visual perception of the bus stop, they do not replicate real-time human motion perception or account for atmospheric conditions like rain, fog, or glare from passing vehicles. The lack of VR testing or real-world prototyping means that movement-based legibility remains only partially explored and would benefit from future dynamic testing environments.

5.6.2 Simulation and Technical Constraints

The lighting simulations were conducted using DIALux evo, which is widely accepted for professional lighting analysis, but has limitations in simulating complex urban scenes involving multiple material finishes, as for example the retro illuminated advertising panel. Furthermore, the lack of a professional license forced the fixture choice into models that held the desired characteristics in teams of beam angle, polar graph distribution and the lumen output was adjusted to obtain the desired one, but the specific fixtures to be implemented could not be texted in the virtual model due to the lack of license. That said, without formal UGR or TI calculations, glare comfort remains an inexplored quality, not an empirically verified one.

Furthermore, color rendering (CRI) and color temperature (CCT) were not varied or tested in simulations. A neutral 3000k was used as a baseline assumption, and no atmospheric or colored light options were explored in depth. This means that emotional tone, time perception, or warmth of the space, which are known to be influenced by CCT, are not addressed in this project and represent areas for future research.

5.6.3 Generalizability and Contextual Constraints

This thesis focuses on a single case study: the Glyptoteket stop on Line 2A in Copenhagen. While this stop was selected because of its representativeness within the 2A line, the findings are not statistically generalizable to all bus stops. Urban context—including ambient lighting and traffic patterns—plays a significant role in how lighting is experienced. As such, the design's effectiveness may vary significantly across other zones, and would require site-specific calibration to perform as intended.

The final design module was developed for a standard shelter typology common across Copenhagen, and while it can be implemented in stops that share this format, it has not been tested on alternative shelter types or in contexts with significantly different urban lighting conditions. For other shelter configurations, further technical adaptation would be necessary.

In stops without any shelter, the physical design itself would not apply, but the design strategy—particularly the movement-based rhythm logic—could still inspire meaningful interventions. Still, this would require rethinking both form and installation methods, something not explored in this thesis.

5.6.4 Standards Compliance and Partial Benchmarking

The thesis uses industry standards (EN 13201-2, CIE 115, EN 12464-2) as benchmarks for comparison in Section 5.4, but not all parameters were fully tested. For example:

TI (Threshold Increment) for glare was not simulated due to software constraints.

UGR (Unified Glare Rating) was not calculated numerically, but inferred based on lighting design practices.

Luminance uniformity (U_0) was visually assessed but not quantitatively calculated in the full horizontal standing plane.

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5.6.5 Design Decisions and Aesthetic Subjectivity

The design favors indirect over powerful. This was a conscious design decision—to reveal the stop gradually, and to align the lighting with movement and perception rather than in a sudden encounter. However, it should be acknowledged that aesthetic response is subjective, and some users may prefer brighter or more immediately recognizable stops.

Additionally, while the proposal positions the stop as a contributor to urban identity, the degree to which this occurs is not measurable within the scope of this thesis. Concepts like *imageability*, *place-making*, and *emotional resonance* are referenced through literature and supported by conceptual alignment, but not tested in the field or through longitudinal studies.

5.6.6 Time and Production Constraints

This thesis was developed within the timeframe of a single semester, during which both research and design development had to occur in parallel. As a result:

Some aspects (like lighting integration details, glare testing, or CCT variation) were not developed beyond schematic level.

Material testing, weather resistance, and maintenance planning of the lighting module were not addressed.

A full-scale mock-up or user-based evaluation of the built system was not feasible.

In summary, this thesis is best understood as a design-research prototype: a framework and proposal that explore how lighting can intervene microscale urban infrastructure into a meaningful moment. While grounded in theory, site observation, and simulation, it is not a fully engineered solution. Its limitations are acknowledged transparently to allow space for future development, adaptation, and testing in real-world conditions.

5.7 Future Work

5.7.1 Field Implementation and User Response Testing

An important next step for this project would be the real-world implementation of the proposed lighting strategy at an actual bus stop. While simulations and user surveys provided valuable insights into perceptual responses, testing the design in its intended urban context would allow for a more comprehensive understanding of how people interact with it in everyday use.

Implementing a prototype on-site would create the opportunity to directly observe user behavior and spatial preferences under real lighting conditions. It would also allow for unstructured and spontaneous interactions that are difficult to fully anticipate or simulate. For instance, observing how people navigate around the shelter, how long they remain inside, or whether certain lighting elements draw their attention could all inform future refinements.

To complement these observations, structured user response methods such as short interviews, quick-response surveys, or even motion tracking technologies could be used. These tools would help evaluate how the lighting affects users' sense of comfort, perceived safety, spatial awareness, and ease of recognition—especially at night or under changing environmental conditions.

While the implementation of a physical prototype was beyond the scope of this thesis, it is seen as a valuable next step that could help connect the design concept with its practical application. Testing the proposal in a real-world setting would offer important feedback that cannot be fully captured through simulation alone, and would support a more grounded understanding of how the strategy performs in everyday urban use.

5.7.2 Integration of Adaptive Urban Lighting

A valuable direction for future development of this research based project can be the integration of responsive lighting technologies. While the idea of an adaptive lighting scheme was part of the initial concept, limitations in time and resources meant that this aspect could not be fully explored within the current scope of the thesis.A future version of the design can implement IoT-based control systems using light sensors to monitor ambient lux levels and automatically adjust the bus stop lighting to maintain an optimal ratio with its surroundings. This strategy, referred to as the Ambient Lux Ratio Strategy, aims to improve the context specific aspect of the shelters. By doing so, it optimizes the brightness and contrast ratios improving both comfort and legibility by ensuring that the shelter's illumination is not overwhelmingly bright inside or insufficiently legible in its urban context.

Through the design process, it became clear that imbalance in brightness was a recurring issue. In certain cases, the shelter can stand out too aggressively or be barely distinguishable, depending on the local lighting conditions of its environment. A sensor-based system would allow for dynamic adjustment of the shelter's internal lighting, preserving a comfortable luminance ratio across a wide range of scenarios—from dark recreational areas to brightly lit commercial streets.

The research already provides a foundation for this kind of responsive approach. In *Appendix A*, each of the 38 stops along Line 2A was documented with its stop type, urban zone, and recorded brightness level. These data points could serve as a reference for establishing contextual lighting thresholds. By setting desired lux ratios the lighting could actively adapt throughout the evening and night, depending on environmental inputs.

Additionally, time-sensitive programming could be integrated alongside sensor feedback, using city-wide lighting schedules as another input layer. For example, certain brightness presets could automatically apply during transition hours (sunset and sunrise, weekends, or high-traffic periods) enhancing both energy efficiency and perceptual performance.

While the version presented in this thesis remains a static prototype, this kind of sensor-integrated approach could help transition the bus stop lighting concept into a more dynamic and context-aware infrastructure. It's a direction that would require further development and testing, but it reflects an ongoing ambition to better align this lighting design with smart cities.

5.7.3 Application to Other In-Between Urban Spaces

Although this thesis focused specifically on the lighting conditions of bus stops, the design principles and research methods developed throughout the project hold broader relevance. Many in-between urban spaces, such as pedestrian underpasses or alleyways, share similar spatial and perceptual characteristics. These are transitional zones, often defined by short durations of occupancy, non-continuous flows of movement, and minimal attention in standard urban lighting strategies.

Like bus stops, these micro-scale environments frequently fall outside the scope of dedicated lighting design and instead rely on spill light from nearby streets or adjacent buildings. As a result, they often lack spatial identity, perceptual comfort, or clarity of use after dark. In many cases, they are treated as functional voids in the city, where lighting serves only the minimum technical standard of visibility.

The findings of this thesis can suggest that such environments deserve more attention. By applying similar strategies—balanced brightness, backlighting, vertical rhythm, and motion-sensitive legibility—lighting design can begin to shape these neglected spaces into more legible, comfortable, and visually engaging elements of the city.

Furthermore, the methodological framework used in this thesis can be adapted to study other transitional spaces. For instance, a pedestrian underpass might be examined using the same speed-based visibility analysis used for cyclists and bus drivers, or a narrow alley could benefit from the exploration of ambient contrast and vertical lighting cues.

In short, the principles developed here are not exclusive to bus stops but are applicable to a range of small-scale urban settings. Extending this research to those spaces could strengthen the role of lighting as a tool for placemaking and micro-scale identity building within the broader urban landscape.

5.7.4 Daylight

While this thesis focused on artificial lighting under nighttime conditions, future research could extend the investigation to include daylight and its interaction with bus stop environments throughout the day. Natural light plays a vital role in shaping spatial perception, and its variation can affect comfort, spatial awareness, and legibility.

Key aspects to explore include shelter orientation, the transparency and reflectance of materials, and how sunlight is filtered through or reflected by the structure. For instance, during the day, the metal vertical panels proposed in this design will not remain visually present but will cast soft shadows and layered reflections that vary depending on the sun's position. This could introduce a subtle daytime rhythm to the shelter’s appearance, reinforcing its identity as a designed moment in the city even when artificial lighting is not active.

In cities like Copenhagen, where daylight hours shift drastically between seasons, these passive lighting effects could help support a more continuous spatial identity. By considering how natural and artificial light interact, future lighting strategies could be extended into truly 24-hour design systems. Understanding daylight effects could help improve the overall experience of the bus stop at all times of day.

CHAPTER VI: CONCLUSION

6. Conclusion

This thesis set out to investigate how lighting design can improve the experience of waiting at Copenhagen's bus stops by responding to user movement, perception, and the surrounding urban identity. The study identified a critical research gap: although public transportation lighting has been studied in relation to metros, trains, and large transit hubs, micro-scale environments such as bus stops remain underexplored. These spaces, while modest in size, play an essential role in the everyday experience of the city and its nighttime identity.

To address this gap, the project formulated a central research question: *How can a lighting strategy that responds to urban movement turn waiting time at bus stops into a safer and more visually engaging urban experience?* The literature review identified key independent lighting parameters—brightness, contrast, and distribution/directionality—and connected them to perceptual outcomes such as comfort, safety, space awareness, and legibility. These variables provided the analytical foundation and framework for the research, but also constitute a possible starting point for other works that aim to study different spaces with similar characteristics and a similar objective.

The analysis phase explored how these parameters and perceptual qualities were reflected in the real-world case study, contextualized in Copenhagen's bus stops (Line 2A). It revealed that poor brightness balance inside the stop affected user positioning and behavior, with people avoiding certain zones due to discomfort. Additionally, the lack of contrast and therefore presence recognition negatively impacted perceived safety, particularly for users approaching by car or bike who struggled to identify whether the stop was occupied. These findings informed the outlining of clear targeted parameters that were necessary to achieve a more perceptually safe and engaging public space.

In response, the investigation was organized into three sub-research questions, each targeting one independent lighting parameter through a dedicated design block:

> *SRQ1: How can the brightness hierarchy between the different lighting layers of the bus stop be rebuilt to improve users' spatial awareness and reduce visual discomfort at bus stops?*

> *SRQ2: Can the use of backlighting influence the visibility of user silhouettes and enhance presence recognition from the surrounding urban environment?*

> *SRQ3: Can a visually recognizable lighting distribution improve the identification of a bus stop at night for different types of approaching users?*

By structuring the inquiry around these three questions, the project aimed to test and refine design strategies for each parameter individually, before integrating them into a comprehensive lighting concept aligned with the original research question.

This thesis contributes to lighting design by expanding how micro-scale public spaces—such as bus stops—are understood, analyzed, and designed. The project raised the hand about how even the most overlooked urban environments carry perceptual, behavioral, and symbolic significance, and states that they can be enhanced through lighting. Several broader insights emerged from this work:

1. Micro-scale environments require micro-scale design logic.

   Bus stops are not miniature versions of large public spaces. Their design must respond to unique spatial conditions—Blurred spatial boundaries, an accumulative impact in the city image and layered traffic flows. Lighting strategies in such spaces must therefore be context-specific.

2. User movement is not a constraint but a design input.

   Traditional lighting practice often assumes static observation. This project shows that user speed and direction can be treated as a core part of design reasoning. Lighting can be calibrated to change perception conditions—what is seen, when, and from where—especially at night.

3. A modular approach supports design clarity in complex conditions.

   When working with multiple independent lighting variables, such as brightness, contrast, and disbritubtion(directionality), one possible strategy is to approach them independently at first. This allows each parameter to be tested, refined, and understood in isolation before integrating them into a comprehensive lighting concept. This approach offers greater control over how perceptual outcomes—like comfort, safety, and legibility—are achieved.

4. Lighting can reveal meaning, not just enable function.

   Lighting can act as a trigger for recognition, presence, and belonging. By comfortably defining space boundaries while playfully *revealing* the presence of people , lighting at bus stops becomes a tool for supporting not just safety and comfort, but also the image of the city at night and its *rhythm.*

This thesis positions the bus stop not as a secondary or residual element of the urban environment, but as an *in-between place*. By treating the bus stop as a designed urban moment and exploring through lighting, how these micro-spaces can contribute to people's experience of the city at night. More broadly, this work illustrates the potential of micro-scale interventions to influence macro-scale urban quality. It suggests the idea that urban identity is not shaped only by city landmarks, but also by the rhythm of the citizens.

Rethinking the bus stop through lighting design becomes then, a way to rethink the city itself.

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Appendices

Appendix A: *Line 2A Bus Stops: Typologies, Urban Zone Classification, and Nighttime Brightness Levels*

#	No.	Stop Name	#	Bus Stop Type	Zone Type	#	Brightness Level (lux)
	1	Tingbjerg Gavlhusvej (Terrasserne)		2	Residental		8
	2	Terrasserne (Åkandevej)		2	Residental		1
	3	Energicenter Voldparken (Åkandevej)		2	Residental		2
	4	Husumvold Kirke (Åkandevej)		2	Residental		4
	5	Veksøvej (Frederikssundsvej)		2	Residental		3
	6	Astrupvej (Frederikssundsvej)		2	Residental		3
	7	Brønshøj Torv (Brønshøjvej)		1	Residental		4
	8	Valløvej (Brønshøjvej)		2	Residental, Recreational		2
	9	Fuglsang Allé (Annebergvej)		2	Residental, Recreational		6
	10	Bellahøjvej (Primulavej)		1	Residental, Recreational		3
	11	Rødkildevej (Godthåbsvej)		2	Residental, Commercial		7
	12	Hulgårdsvej (Godthåbsvej)		1	Residental, Commercial		9
	13	Rønnebærvej (Godthåbsvej)		2	Residental, Commercial		6
	14	Grøndal St. (Godthåbsvej)		2	Residental, Commercial		6
	15	C.F. Richs Vej (Godthåbsvej)		1	Residental, Commercial		8
	16	Tesdorpfsvej (Godthåbsvej)		2	Residental, Commercial		7
	17	Ndr. Fasanvej (Godthåbsvej)		2	Residental, Commercial		4
	18	Aksel Møllers Have St. (Godthåbsvej)		2	Residental, Commercial		5
	19	Falkoner Allé (Rolighedsvej)		1	Residental, Commercial		9
	20	Det Biovidenskabelige Fakultet (Rolighedsvej)		2	Residental, Commercial		7
	21	H.C. Ørsteds Vej (Rosenørns Allé)		2	Residental, Commercial		7
	22	Forum St. (Rosenørns Allé)		2	Residental, Commercial		9
	23	Vester Farimagsgade (Gyldenløvesgade)		2	Commercial, Cultural		11
	24	Rådhuspladsen (Vesterbrogade)		2	Commercial, Cultural		20
	25	Hovedbanegården Tivoli (Bernstorffsgade)		3	Commercial, Cultural		10
	26	Glyptoteket (Tietgensgade)		3	Commercial, Cultural		8
	27	Stormbroen Nationalmuseet (Vindebrogade)		2	Commercial, Cultural		15
	28	Gammel Strand St. Christiansborg (Vindebroga		2	Commercial, Cultural		1
	29	Holmens Kirke (Holmens Kanal)		1	Commercial, Cultural		12
	30	Knippelsbro (Torvegade)		1	Residential, Cultural		12
	31	Christianshavn St. (Torvegade)		1	Residential, Cultural		8
	32	Skt. Annæ Gade (Prinsessegade)		1	Residential, Cultural		7
	33	Bodenhoffs Plads (Prinsessegade)		1	Residential, Cultural		8
	34	Arsenaløen		2	Industrial, Recreational		5
	35	Galionsvej (Danneskiold-Samsøes Allé)		2	Industrial, Recreational		3
	36	Fabrikmestervej Operaen		2	Industrial, Recreational		4
	37	Margretheholm (Refshalevej)		1	Industrial, Recreational		2
	38	Refshaleøen (Refshalevej)		1	Industrial, Recreational		4

Appendix B: User Interview *Transcript- Pedestrian*

Interview 1: Pedestrian at City Center (– Line 2A)

Interviewee profile:
Name: Sara K.
Age: 31
Occupation: Graphic Designer
Residence: Vesterbro, Copenhagen
Frequency of use: Uses line 2A from the city center 3–4 evenings a week, usually between 6–8 p.m.

1. When you're here in the evening or night, how would you describe the comfort of the stop?

It's fine, I guess — it keeps the rain off, and there's a bench, which is nice. But it can feel a bit cold at night. The lights work, but they're not super inviting. I usually just look at my phone and hope the bus comes quickly.

2. Do you feel comfortable waiting here at night?

Most of the time, yes. There are people around and it's not too quiet. But sometimes when it's later or less busy, and if I'm standing alone, I feel a bit cut off. Especially when cars pass behind me.

3. Do you feel like you're part of what's going on around you, or kind of isolated?

More isolated, I'd say. It feels like I'm standing in a box, waiting. If something's happening around me, I might not notice until it's right there.

4. Can you usually see the faces of people around you clearly? And do you feel like they can see you?

Hmm... not always. If someone walks by the stop, I sometimes can't tell who they are unless they're really close. And I'm guessing they probably can't see me well either, especially if I'm sitting at the back. The light's not bad, but it's not great either.

5. Is the bus stop easy to recognize when you approach it at night?

If you know it's there, sure. But I don't think someone new to the area would spot it right away at night. It kind of blends into everything else. There's no big light or anything that makes it stand out.

6. If you could change one thing about how this stop feels at night, what would it be?

Make it feel warmer. I mean like cozier. Maybe softer light, that makes it look like a nice place to wait.

Appendix C: User Interview *Transcript- Bus Driver*

Interview 2: Bus Driver – Line 2A (Central Station)

Interviewee profile:
Name: Ali M.
Age: 45
Job Title: Bus Driver (Movia, Line 2A)
Experience: 12 years as a driver, 6 of them on 2A
Schedule: Evening shifts, typically from 3pm to 11pm

1. How easy is it to see the stop when you're coming up to it at night?

You can see the stop, yeah, but it's not always clear where people are. The stop doesn't stand out that much, and if someone's not standing near the edge, I might not notice them right away — especially if the street is busy or it's raining.

2. Is it easy to see people waiting inside the stop?

Sometimes. If they're standing near the front, I can usually spot them. But if they're sitting back or standing in the shadows, I might miss them until I'm right at the stop. The glass reflects, so with lights from cars or shops, it can be hard to see.

3. Can you usually see if someone is trying to wave or signal you?

Not always. If they wave early and they're close to the front, that helps. But if they wave too late or they're too far back in the shelter, I might not see it in time — especially with all the traffic.

4. Does anything about the lighting at the stop make driving in or pulling over harder?

It's not bad, but It doesn't catch your attention. It would help if the shelter was lit a little better.

5. If you could suggest one small change to improve it for you and the passengers, what would it be?

I'd add light — something that makes the shelter stand out more, and helps me spot people easier. Nothing flashy, just something that makes it more visible at night.

Appendix D: User Interview *Transcript- Cyclist*

Interview 3: Cyclist Passing a Single-Shelter Bus Stop

Interviewee profile:

Name: Mathias L.

Age: 27

Occupation: Master's student in Architecture at KADK

Commute: Bikes daily from Nørrebro to Refshaleøen, typically around 18:00–19:00.

1. How visible is the bus stop to you when cycling past it at night?

I notice it because I go past it every day, but it's not something that really stands out. At night, it kind of fades into the rest of the street. Unless someone is moving inside or the bus is actually there, I could easily miss it.

2. Does the stop feel like a clear and distinct place on the street, or does it blend in?

It mostly blends in. If you didn't already know it was a bus stop, I'm not sure you'd catch it in time.

3. Do the lighting conditions affect how you perceive or react to it when cycling?

Yes, definitely. Sometimes someone steps out to catch the bus and I barely notice them until I'm right there. The lighting inside the stop doesn't help showing the people.

4. Is there anything about the bus stop that makes you slow down or be more cautious?

Not really — only if I see a bus pulling in or someone suddenly moving. Otherwise, I keep going.

5. What would you change or add to the lighting at this stop?

I'd add something simple but noticeable — something that doesn't flash but tells you, "this is a stop, people might be here.

Appendix E: *Observation Notes - 11.04.2025 Friday from 19:30–21:00*

Time	# of People	Zones Used	Alone / Group	Behavior	Notes
19:30	3	A, B, C	2 alone, 1 pair	Waiting, phone, light conversation	One user outside in Zone C, pair stood in front (B)
19:45	4	A, B, D	3 alone, 1 pair	Avoiding D, quick repositioning	One briefly stood near ad panel (Zone D) then moved
20:00	5	A, B, C	3 alone, 1 group	Quiet waiting, some phone use	Group stayed near front of shelter
20:20	2	A, E	2 alone	One leaned behind (Zone E) briefly	Left after few minutes
20:35	4	B, C	2 alone, 1 pair	Chatting, scanning road	Used sidewalk and front; inside remained mostly empty
20:50	3	B, C	2 alone, 1 pair	Waiting, avoiding ad panel	Zone D was bypassed by all

Appendix F: *Observation Notes - 12.04.2025 Saturday from 20:30–22:30*

Table 03: Saturday 20:30–22:30

Time	**# of People**	**Zones Used**	**Alone / Group**	**Behavior**	**Notes**
20:30	4	B, C	3 alone, 1 pair	Looking around, phone, chatting	All avoided interior and ad side
20:50	5	B, C, E	3 alone, 1 group	One stood briefly behind shelter	Group used front (Zone B), none went near ad panel
21:10	6	A, B, C	3 alone, 1 group	Group chatting, others repositioned	One moved from inside (A) to sidewalk (C)
21:40	4	B, C	2 alone, 1 pair	Quiet use, all remained in front	No one used back or ad panel side
22:10	5	A, B	3 alone, 1 pair	One sat briefly in A, others in B	Most preferred standing in front
22:25	3	C	3 alone	Phone, leaning on outer rail	Complete avoidance of interior

Appendix G: *Survey - Presence Recognition Inside the Bus Stop Using Backlighting*

Survey – Presence Recognition Inside the Bus Stop Using Backlighting

This short visual survey is part of a master's thesis in Lighting Design at Aalborg University. The aim is to understand whether adding **backlighting** to the rear wall of a bus stop helps make people waiting inside more visible at night.

You will be shown **two images**:

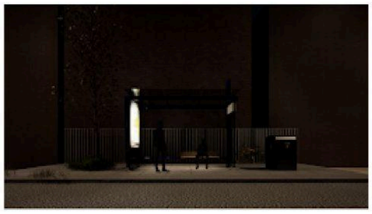
- **Image A:** Current lighting condition of the bus stop at night
- **Image B:** Same bus stop with an added backlit surface behind the bench, designed to improve visibility of people inside.

Your answers will help evaluate whether this lighting strategy could improve comfort, safety, and communication between bus users and passersby (drivers, cyclists, pedestrians).

* Indicates required question

1. In which of these two images can you more easily tell if someone is waiting at the bus stop? *

Mark only one oval.



- Option 1
- Option 2
- I don't see a significant difference

Appendix H: *Survey - Nighttime Recognition of Bus Stops Using Vertical Lighting*

Survey – Nighttime Recognition of Bus Stops Using Vertical Lighting

Thank you for participating in this short visual perception survey. The aim is to understand whether the addition of vertical lighting behind a bus stop can improve its visibility and recognition during nighttime.

You will be shown **three image pairs**, each simulating the viewpoint of a different user:

- **Pedestrian** (sidewalk)
- **Cyclist** (bike lane)
- **Bus Driver** (road)

Each pair contains two images:

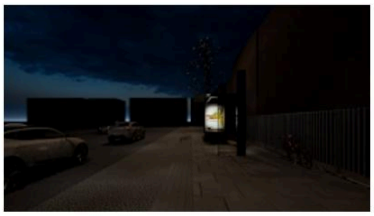
- **A:** The current nighttime condition of the bus stop
- **B:** The same bus stop with added vertical lighting panels behind the shelter

Please answer **one question per image pair**, followed by a final general question at the end. This survey supports a master's thesis in Lighting Design at Aalborg University.

* Indicates required question

1. From the pedestrian perspective, in which image can you recognize the bus stop more clearly? *

Mark only one oval.



Option 1

Option 2

I don't see a significant difference

2. From the cyclist perspective, in which image can you recognize the bus stop more * clearly?

Mark only one oval.

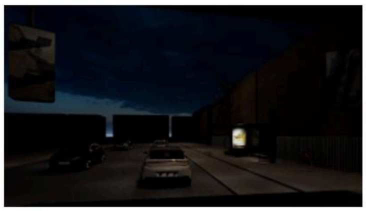
Option 1

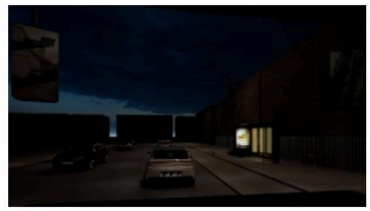
Option 2

I don't see a significant difference

3. From the driver's perspective, in which image can you recognize the bus stop more clearly? *

Mark only one oval.





( ) Option 1

( ) Option 2

( ) I don't see a significant difference

4. If this lighting solution were implemented at multiple bus stops in the city, do you think it would help you recognize or remember the stops more easily? *

Mark only one oval.

( ) Yes
( ) No
( ) Not sure

Appendix I: *Table - Benchmarks*

	Parameter	Recommended Value	Source & Reference
1	Horizontal illuminance	5–15 lux	EN 13201-2:2015, Table 2 – Lighting classes for pedestrian areas (P-class: P3)
2	Vertical illuminance	2–10 lux (1.5 m)	CIE 115:2023, Clause 6.5 – Pedestrian visibility and facial recognition
3	Uniformity (U_0)	≥ 0.4	EN 13201-2:2015, Table 2 – Minimum overall uniformity for pedestrian areas (P-class: P3)
4	Color Temperature	3000K / warm	UITP Guidelines (2010); Danish municipal strategies (e.g., København's Bystrategi)
5	Color Rendering Index	CRI ≥ 70 (preferably >80)	CIE 115:2023, Clause 4.5 – Lighting quality for facial recognition and safety
6	Glare control - TI (open areas)	TI ≤ 15%	EN 13201-2:2015, Table 2 – TI values for P-class lighting
7	Glare control - UGR (shelters)	UGR < 22 (max); < 19 preferred	EN 12464-2:2014, Table 1