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LIGHT AND HEALTH IN UNDERGROUND PUBLIC SPACES FOR THE WELL-BEING OF ALL

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Abstract: Ensuring adequate lighting in underground public spaces is a fundamental prerequisite for their accessibility and their use. Without sufficient illumination, these environments become difficult to navigate, compromising their usability and safety. Artificial lighting must, therefore, meet essential operational criteria, supporting visibility, orientation, and security for both users and personnel, related to comfort and well-being for all.

This article examines the conceptual and experiential quality of lighting in metro stations, adopting a user-centric perspective that integrates spatial, functional, and sensory dimensions. It aims to highlight the essential tools of thoughtful lighting design to enhance the development of universal and inclusive underground public spaces.

Keywords: Design, station, lighting, metro, accessibility, art public

1. INTRODUCTION

Access to underground spaces remains challenging for many users due to physical, psychological, and sensory barriers. Fear of enclosed environments, feelings of confinement or insecurity, and memories of harassment or aggression are all factors that influence perceptions of safety and comfort. Such ambivalence is historically grounded, as subterranean spaces have long carried symbolic, religious, and defensive connotations (Leclerc, 2010). In this regard, Plato's allegory of the cave acquires renewed significance: it is through light that alternative spatial realities become accessible.

Grounded in the premise that light is a condition for the appropriation and usability of underground spaces. It examines how lighting can sustain urban continuity between surface and subterranean public environments, with particular emphasis on their capacity to meet essential requirements for human health and well-being. Adopting an empirical approach, it investigates the roles and effects of lighting in metro stations by combining theoretical perspectives with practical analysis of spatial components. Drawing on contemporary research, this study delineates best practices in lighting design as a means of user-centric frameworks that improve urban health, inclusivity, and overall well-being.

2. WHY LIGHT IS IMPORTANT FOR HUMAN BEINGS IN UNDERGROUND SPACE?

Light is essential not only for vision but also for regulating physiological processes, mood, and behaviour. While natural light serves as the primary biological synchroniser, technological advancements have led to the development of human and circadian lighting systems that replicate natural daylight variations indoors. These

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systems adjust both intensity and spectral composition throughout the day, enhancing morning alertness and evening relaxation, with documented benefits for mood, cognitive performance, and sleep quality in schools, workplaces, and healthcare settings (Figueiro et al., 2017; Browning et al., 2020).

In urban planning, particularly in underground and metropolitan areas, dynamic biologically effective lighting can improve user comfort, reduce disorientation, and enhance perceived safety. Cities such as Stockholm, Munich, or Seoul have piloted innovative strategies, including daylight-mimicking LED systems based on the Human-Centric Lighting (HCL) approach, artistic light installations, and the integration of greenery in metro stations, to improve spatial experience and psychological well-being (Rossi et al., 2012; Frontiers in Psychology, 2021). The main health risks and benefits of lighting in subway environments are summarised in Table 1.

Incorporating artificial lighting as a determinant of urban health supports the planning of health-promoting infrastructure within the "Health in All Policies" (HiAP) framework and aligns with the United Nations Sustainable Development Goals, particularly SDG 3 (Good Health and Well-Being) and SDG 11 (Sustainable Cities and Communities).

Table 1. *Summary of the impact of natural and artificial light on human health and well-being, with a focus on different approaches to the design of underground and metro environments.*

Topic	Health Effects: Benefits / Risks	References / Examples
Natural Light	Regulates circadian rhythms, improves mood, supports vitamin D synthesis, and enhances cognition. Lack of daylight leads to disorientation, fatigue, and stress.	(CIE, 2019); (Vandewalle et al., 2009)
Artificial Light	Can disrupt circadian rhythm, affect sleep, mental health, and ocular health if poorly managed.	(Lucas et al. 2014); (Figueiro et al. 2017)
Artificial Light (Metro)	Beneficial when appropriately adapted and timed according to the duration and moment of exposure. Insufficient or poorly designed artificial lighting can create a sense of oppression, discomfort, or even anxiety, making the underground space feel unwelcome and off-putting.	(Rossi et al. 2012); (Frontiers in Psychology, 2021;) (Terrin, 2008),
Simulate daylight, artistic lighting, green design	Reduces stress, evokes emotion, facilitates natural orientation and calming effects, provides a pleasant feeling and improves user experience.	Stockholm Metro, London Underground, STM Montreal
Human-Centric Lighting	Support circadian health, improve alertness and productivity, improve accessibility, and reinforce the feeling of security and comfort	Tunable LEDs in offices, hospitals, metros
Public Health Policy	Support urban design with healthy lighting in transport and public spaces	Urban resilience policies; WHO Healthy Cities; SDGs (3, 11);

Psychological responses to lighting, such as those illustrated by the Kruithof effect[3], indicate that users generally prefer warm light at lower illumination levels and cooler light at higher intensities. Although this phenomenon remains a subject of debate, it highlights the need to align lighting conditions with users' perceptual comfort and cultural expectations. Emerging research further suggests that highly correlated colour temperature (CCT) lighting may enhance alertness, offering new directions for the design of lighting in transit environments and beyond (Figure 1).

[3] The Kruithof effect, or Kruithof curve, identifies optimal combinations of colour temperature and illuminance that are perceived as pleasant and natural, offering a valuable framework for comfortable interior lighting design.

***Figure 1**. From left to right: T-Centralen metro station in Stockholm[4], Elisabeth line in London and Place-d'Armes in Montreal.*

However, not all lighting is beneficial. Inappropriate lighting, whether overly intense, poorly directed, or mistimed, can disrupt circadian rhythms, impair sleep, increase stress, and negatively affect mental health. Evening exposure to blue-enriched light, for instance, may suppress melatonin production, delay sleep onset, and contribute to chronic sleep deprivation, which is itself linked to cardiovascular, metabolic, and psychological disorders (Lucas et al., 2014; CIE, 2019).

3. LIGHT AND UNDERGROUND SPACE

However, light plays a central role in the design of public spaces, acting as a universal language that conveys orientation, understanding, and emotion (Matic, 2018). It shapes spatial perception and directs visual attention, functions that are particularly critical in underground environments, which are often perceived as disorienting or even hostile.

This is why designing lighting for underground spaces requires careful consideration of context-specific constraints, such as geotechnical conditions, humidity, the absence of natural light, safety and accessibility requirements. These factors directly influence architectural and technical decisions. Strategies such as covered trenches, the reuse of existing cavities, and spatial developments around access points are often employed to bring light into user pathways, improve spatial legibility, reveal volumes, and enhance perceived safety (Palisse, 2017).

Beyond functional illumination, the quality of light is a major user-centric concern. Monique Labbé (2014) emphasises the importance of integrating natural light, open views, and visual cues within a sensitive design approach. Louis Kahn similarly advocates for the inclusion of natural light, even in minimal amounts, to reveal materiality and spatial depth, qualities often lost with static artificial lighting (Kahn,1996). Chelkoff and Thibaud explore how light intensity influences spatial perception: when strong, it reduces the feeling of being underground; when dim, it heightens the sense of enclosure (Chelkoff and Thibaud,1997). The nature of the light source and its integration are therefore decisive, as shown in the work of Ponizy, who demonstrates how concealed luminaires can enhance the immersive quality of a space (Ponizy, 2016).

In some environments, such as metro stations or underground shopping centres, the absence of natural light has become normalised. However, this practice does not guarantee a satisfactory spatial ambiance. In certain cases, natural light must even be excluded (for reasons of thermal performance, security, or waterproofing), allowing for more precise control of artificial lighting. Yet insufficient lighting can negatively impact perceived safety and diminish the quality of the spatial experience (Cousseau, 2019).

Lighting in underground environments transcends its technical function; it is a complex driver of architectural, sensory, and social quality. As a design component, it calls for an integrated and multidisciplinary approach that considers the full range of technical, perceptual, and sensitive factors shaping user experience (Figure 2). When technical and functional performance, atmosphere, and comfort are brought into alignment, lighting becomes a powerful tool for humanising infrastructure.

[4] All photos in this paper, unless otherwise indicated, are subject to © Gordana Micic.

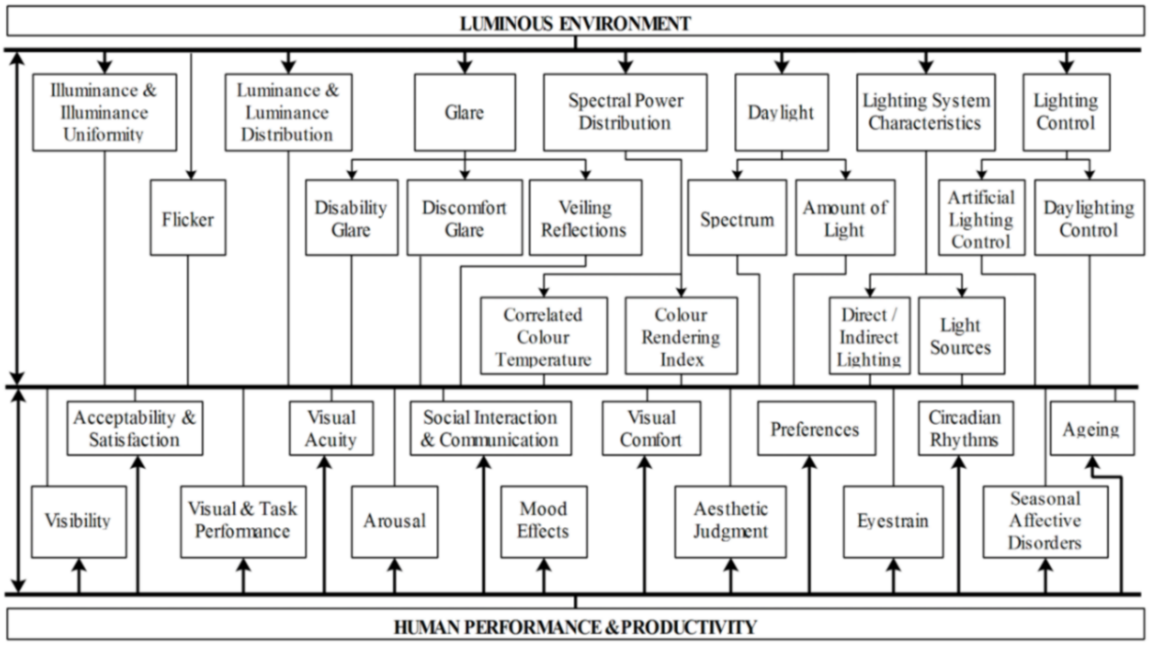

Figure 2. *Co-relation between Luminous environment and Human performance & productivity in design. Source: (Gligor, 2004)*

Lighting design in underground public spaces, such as metro stations, represents a complex challenge situated at the intersection of technical demands, functional constraints, and sensory aspirations. These enclosed, infrastructure-heavy environments require thoughtful design to ensure safety, guide passenger flows, and create atmospheres conducive to comfort and spatial orientation.

4. DESIGNING LIGHT: TOWARDS A USER-CENTRIC APPROACH

Historically, lighting in such contexts has followed a predominantly technicist approach, governed by strict regulatory standards. This orientation reflects the need for high levels of safety, constant visibility, maintenance efficiency, and energy performance. Lighting was thus primarily considered as a technical system to be optimised. Network operators often impose additional, sometimes overly restrictive requirements, further limiting designers' creative freedom and leading to the homogenisation of atmospheres across different stations. Yet this approach is increasingly being challenged in the face of evolving urban contexts and growing user expectations for more inclusive, experience-oriented environments.

In response, there is a pressing need to move toward more holistic practices that reconcile technical requirements with sensory and emotional dimensions. Lighting becomes not just a means of illumination, but also a tool for ambiance, wayfinding, and the enhancement of spatial qualities, capable of addressing both functional imperatives and users' perceptual and affective needs.

Light accompanies the movement of users, and by mastering variations in colour temperature, intensity, and the interplay of light and shadow, while maintaining coherence with architectural form and spatial volumes, designers can create environments with strong identity and meaning. Human spatial perception is inherently multisensory; thus, animating space through a coordinated scenography, architectural, artistic, and urban ensures that sensory information is harmoniously conveyed, producing a fluid and comfortable spatial experience (Figure 3). In contrast, conflicting sensory cues can cause perceptual dissonance, leading to discomfort or confusion. From this perspective, ensuring sensitive coherence becomes essential to facilitating an intuitive and pleasant reading of the environment.

Lighting can adopt variable tones and colours informed by actual or desired movement patterns, reflecting the diverse mobility habits of users. In some cases, lighting systems are adaptive, responding to user density and time of day, while simultaneously guiding movement and highlighting preferred pathways. By doing so, they not only facilitate navigation but also support intuitive wayfinding.

Figure 3. *The Sensual City Journey. Source : Sensual City Studio in Thresholds.*

The transformative properties of light, which enhance and reveal the expressive character of architectural forms, are fundamental to establishing a unique spatial identity. In this sense, lighting becomes an active design element, both functional and symbolic, that contributes to the legibility, atmosphere, and distinctiveness of underground public environments.

4.1. Look at Lighting Quality

Lighting design in underground public spaces is structured around two complementary and inseparable types of light: general lighting and ambient lighting. Together, they shape spatial legibility, sensory quality, and user experience. General lighting ensures overall visibility, visual comfort, and safety. It provides uniform illumination along circulation routes and maintains light levels appropriate to the functional use of the space. In contrast, ambient lighting introduces nuance through contrasts, shadows, rhythms, and highlights. It sculpts volumes, defines pathways, and enhances spatial orientation. By revealing architectural details, it contributes to intuitive navigation, a calming atmosphere, and a stronger sense of place, all of which reinforce the feeling of safety throughout the journey.

When conceived from a user-centric perspective, the articulation between general and ambient lighting must adhere to the principles of universal accessibility to allow everyone to travel in comfortable and pleasant conditions. Working in synergy, these two lighting modes create spaces that are functional, legible, balanced, and adaptable to ensure a high quality of experience throughout the user journey.

Despite this, in practice, lighting design is still introduced too late in the project timeline, typically during the execution phase. This delayed integration limits designers' flexibility and can result in additional costs. To guide decisions and ensure consistency across infrastructure, several transit authorities have developed thematic guidelines that include dedicated lighting chapters. Authored by technical and institutional experts, these documents serve as design frameworks. However, interpretations of these guidelines vary among designers, influencing how lighting is conceptualised and implemented in underground environments.

The case of Brussels illustrates this evolution. The development of the '*Directives relatives à la conception des stations de métro de Bruxelles : Stations nouvelles – Projets de rénovation'*[5] established a collaborative, cross-disciplinary process which included all stakeholders involved with accessibility 'user expert'. This approach demonstrated the value of combining operating user perspectives to develop not only enlightening solutions but also meaningful compromises between technical efficiency and aesthetic ambition, both literally and figuratively.

From this study, while crossing other different research and prescriptions, we propose a synthesis of the key requirements and constraints shaping lighting design in underground public spaces, as outlined in Table 2. These constraints provide a framework that guides design practice, posing a creative challenge for designers, who must balance ambition with feasibility within the limits of infrastructural realities.

[5] Translation in English: '*Brussels Metro and Pre-Metro Station Design Directives: New stations – Renovation projects'*

Table 2. *A user-centric and cross-disciplinary categorisation of lighting design criteria for underground public spaces: requirements and constraints and insights from diverse sources.*

Category	Requirements	Constraints
Contextual and urban	Take account of the urban situation and the surrounding light levels by enhancing accesses Encourage the contribution of natural light The shape and orientation of the building should encourage the penetration of natural light in a coherent manner Contribute to the creation of an identity for access and buildings as an urban landmark.	Take account of areas protected as cultural heritage, which restricts the possibilities for integration Deal with pre-existing street furniture, which can create obstacles No light pollution of the environment and vice versa.
Basic features	A gradual transition in lighting from the outside to the inside. A level of lighting that is uniform and sufficient for everyone, with the quality of daylight, throughout the dominant pathway: from the outside to boarding. Ensuring the visibility of the area Facilitating orientation and legibility of the route - luminous guide-lines, reinforcement of signage and landmark elements such as works of art and the like. Improve lighting in high-risk areas (staircases, escalators, ramps, lifts, doors, signage, reception, ticket validation machines, platforms, toilets, etc.).	Complexity of traffic flows Eliminate shaded areas on dominant routes Avoid the risk of glare Respect the minimum prescribed lighting level. Avoid excessive light pollution
Atmosphere and comfort	A pleasant and soothing atmosphere with diffused light Prioritise natural light, or a light spectrum close to natural light Reduce the feeling of confinement Ensure smooth light transitions Integrates art works and cultural activities	Risk of monotony or over-stimulation Deep or very large spaces that are difficult to homogenise Avoid permanent light integrated into the floor and/or frontal light in the walls to avoid glare
Structure and materiality	Considering and enhancing the structure and volumes in an integrated way Working with the properties of materials: diffuse reflection, texture, etc. Support and enhance the artistic and architectural heritage. Use materials and colours in an intelligible way to enhance the luminosity of the space	No direct glare - hide the source of light Easy access at all weather Easy maintenance
Safety and security	Limiting shaded areas conducive to insecurity Integrating emergency and lighting systems Integrating stand-alone emergency lighting Ensuring visibility for surveillance cameras Blue lighting for high-risk areas (anti-social behaviour, drug use or similar)	Increased lighting in high-risk areas: staircases, escalators, lifts, access control lines, etc. Emergency conditions (evacuation, breakdown)
Economy and maintenance	Use lighting fixtures that are durable and resistant to moisture, physical damage (depending on location) and easy to maintain.	Installation easily and permanently accessible Budgetary limitations
Sustainability and environment	Optimising performance, comfort and energy efficiency to reduce energy consumption Intelligent lighting management with monitoring: dimming (peak times, presence detection), adjusting lighting according to natural light, etc. Favour energy saving, recyclable or recycled luminaires.	Technical constraints of the subsoil (ventilation, heat, humidity) Use of standardised and interchangeable materials Integration into old or complex structures
Innovation and experimentation	Original visual features Integration of innovative lighting systems	Need for compatibility with current standards

High-quality lighting design therefore relies on a delicate balance between uniformity, controlled contrast, and coherent atmospheres to meet both functional needs and perceptual expectations across diverse user groups. Design prescriptions and guidelines offer shared criteria that should foster consistency in station layout. Some operators, however, add specific qualitative requirements that may appear more restrictive. Yet this dual function, ensuring performance standards and communicating expectations clearly to less experienced designers, can streamline collaboration and save time, particularly in relation to universal accessibility.

It is a fact that such constraints, expressed through design charters, can limit the creative freedom of architects and lighting designers, especially concerning natural light integration, visual openings, or ambiance diversity. While architects often view these limits as restrictive, lighting designers may find them intellectually stimulating. Designing within constraints becomes a creative challenge, demanding ingenuity from the design team. The ability to argue and propose variants allows for the mitigation of normative limitations, especially when it comes to enhancing visual comfort and reducing the sense of enclosure.

4.2. Between the Measurable and the Immeasurable

Evaluating the quality of lighting in underground environments involves a multifaceted approach, at the intersection of photometric performance and subjective perception (Flynn et all, 1992). While certain sources of visual discomfort, such as glare, flicker, or poor colour rendering, can be reliably quantified, the broader notion of visual comfort remains difficult to measure comprehensively. This complexity also arises from the interaction between the three-dimensional boundaries of space and the temporal dimension of movement, both of which shape and transform the spatial perception of the physical environment (Capron, 2021).

In his doctoral research, Jordi Nonne proposes a structured framework for evaluating visual comfort quality, articulated around three core dimensions: performance, ambiance, and comfort. His model is interesting because it attempts to go beyond strictly normative approaches by integrating the sensory qualities of light into spatial design. It incorporates six key photometric parameters, which must be assessed holistically:

- Illuminance level (lux): general visibility.
- Uniformity: Providing consistent light distribution to avoid abrupt changes in brightness that disrupt perception.
- Contrast: Essential for spatial legibility, as it shapes depth perception and volumetric reading through transitions between light and shadow.
- Colour Rendering Index (CRI): Accurate colour fidelity supports spatial recognition and aesthetic experience.
- Correlated Colour Temperature (CCT): Influences overall atmosphere; to balance comfort and functionality. Designers must also consider the spatial positioning of light sources and their relation to the black-body locus in the chromatic space.
- Light distribution: Modulates spatial experience and visual hierarchy. Each lighting device produces zones of higher and lower luminance, Sa and Su, respectively. The ratio Sa/Su indicates the degree of diffusion: a balanced ratio correlates with enhanced visual comfort (Nonne, 2015).

Although its practicality remains limited, this model paves the way for a more nuanced evaluation of lighting quality, integrating functional performance with subjective perception and artistic and architectural expression. It allows for the generation of multiple lighting scenarios that accommodate individual perceptions, particularly relevant in complex environments such as underground public spaces.

Drawing from several standards and other technical sources, recommended measurable values on the dominant path for metro stations are detailed in Table 3. These measurements must be conducted across multiple sampling fields representative of each spatial zone. While such reference values provide essential design benchmarks, they may be adapted according to station-specific boundaries and characteristics such as spatial configuration and surface materials. The overarching goal remains the same: to ensure sufficient, coherent, and comfortable lighting that enhances the user experience in constrained underground settings.

Achieving balanced lighting uniformity, particularly critical for universal accessibility, requires careful calibration across the entire user journey. Uniformity is necessary because it expels excessive contrasts, which can cause discomfort or distraction. Most indoor lighting designs prioritise appropriate illuminance levels, even though the human eye responds primarily to luminance, or light reflected from surfaces, rather than the direct intensity of the sources.

Table 3. *Recommended measurable values on the dominant path for metro stations, according to different sources.*

Area/Assignment	Illuminance level (Lux)	Uniformity (U_0)	IRC Max (Ra)	CCT (K)
Access hoppers: External / Interior	200-300	≥ 0,4	≥ 80	3500–4500
Elevator - cabin	150	≥ 0,4	≥ 80	3000–4000
Circulation zones	200	≥ 0,4	≥ 80	3000–4000
Welcoming hall	200-300	≥ 0,6	≥ 80	3500–4000
Ticket machine / ATM	300-500	≥ 0,5	≥ 80	3500–4000
Control zone / gates	200-300	≥ 0,5	≥ 80	3500–4000
Boarding platforms	200	≥ 0,4	≥ 80	3000–4000
Public sanitary facilities	200-300	≥ 0,5	≥ 80	3000–4000
Technical areas	150-200	≥ 0,6	≥ 80	4000–5500
Overnight maintenance	70	≥ 0,6	≥ 80	4000–5500

Despite the value of measurable data, particularly concerning visual discomfort, certain subjective dimensions remain beyond the scope of current instrumentation. These "sensitive" factors, as described by several authors, are rooted in individual experience and perception. While not directly measurable, they play a crucial role in user appropriation of space. Based on various sources, they can be summarised as follows:

- Overall perceived visual comfort: A product of multiple factors, like uniformity, contrast, colour temperature, and ambiance, combined with personal variables such as age, visual fatigue, preferences, and visual impairments - difficult to guarantee universally pleasant ambient conditions.
- Perception of ambiance: Contributes to impressions of intimacy, calm, dynamism, or stress. Ambiance results from a nuanced combination of intensity, distribution, colour temperature, shadows, and their interaction with structure, materials, and spatial volumes.
- Perception of safety: Lighting may affect users' feelings of safety independently of measurable illuminance values, particularly in ambiguous, isolated, dark or visually cold environments.
- Aesthetic perception: Lighting that enhances the spatial and material qualities of a space can foster emotional satisfaction and a positive experience. Conversely, inadequate lighting can diminish spatial legibility and reduce user comfort.

However, the challenge lies in reconciling quantifiable criteria with the more subjective dimensions of visual comfort, which engineers may regard as immeasurable. Accordingly, it is essential to test different lighting scenarios using mock-ups and to engage not only technical experts but also users, or even "expert users" with experience in universal accessibility. Depending on the context, broader user consultations should also be conducted to ensure the proposed solutions meet the diverse needs and expectations of all users.

5. LOOKING FOR USER-CENTRIC CREATIVE LIGHTING : SOME EXAMPLES

To illustrate our insight, we present a series of atmospheric sequences that accompany users throughout their journey in a metro station. These successive environments are conceived as a visual landscape and as a natural extension of the surrounding urban context. Each sequence serves as a spatial landmark, inviting either contemplation or reorientation, with its own distinct identity in which lightning plays an integral and inseparable role.

1. In the urban landscape, the first step for users is to identify the station entrance. Backlit signage, featuring the metro logo or station name, must stand out clearly as well by night as by day, to ensure visibility and intuitive access for all users (Figure 4, left and centre). Directions, network lines with real-time arrivals, connections, and info services that are available need to be displayed at strategic points and tailored to the requirements of people with reduced mobility (Figure 4, right).

Figure 4. *Day and night retro-lit station totems (left and centre) and information totems (right) at Union Station in Los Angeles.*

2. Another way of enhancing the visibility of a metro station is the creation of a surface-level kiosk. As illustrated in Figure 5, the design emphasises a structure that optimises natural light during the day, while inverting the effect at night to become a luminous beacon. Light and architecture form a whole.

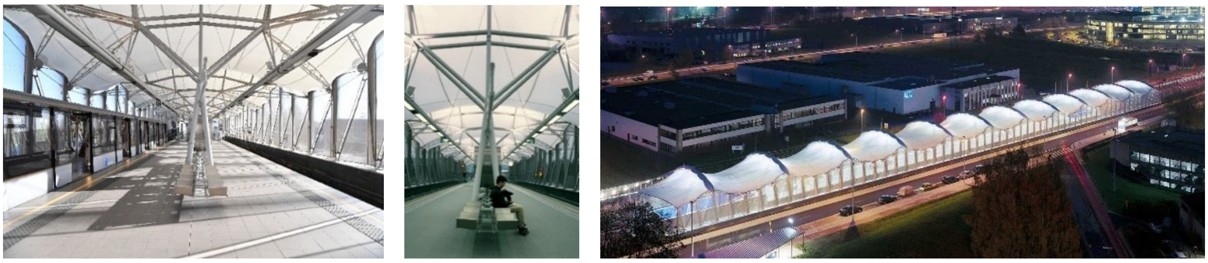

Figure 5. *Erasme metro station, Brussels. Images © Samyn and Partners & STIB-MIVB.*

3. Urban constraints do not always permit straightforward access between underground stations and the surface. In response, a multifunctional solution has been developed, integrating a tree planter, seating, and a skylight into a single urban element, bringing natural light into the station while enhancing the public space above (Figure 6).

Figure 6*. Trône metro station, Brussels.*

4. In spaces where daylight is absent, designer Barbara Hediger[6] creates the illusion of the sky, offering a sense of time and light variation by intensity and colour. This approach helps reduce the feeling of confinement, a key consideration in enclosed environments like underground stations and workspaces (Figure 7).

Figure 7. *Space Belgolaise - Dispatching STIB-MIVB, Brussels. Images © Barbara Hedigher*

[6] According to Barbara Hediger, lighting designers are essential to converting architectural vision and creating unique ambiances. Particularly when it comes to '*orchestrating*' light to facilitate seamless transitions between different spaces. Online interview, 10 July 2025, 11 a.m.

5. Enhancing lighting at the ends of stairways improves visibility for individuals with visual impairments. The use of green and red lighting reinforces directional cues and supports intuitive wayfinding (Figure 8, stairs and escalators). Similarly, employing distinctive colours for elevators makes them easier to locate, contributing to a more navigable and accessible environment (Figure 8, right).

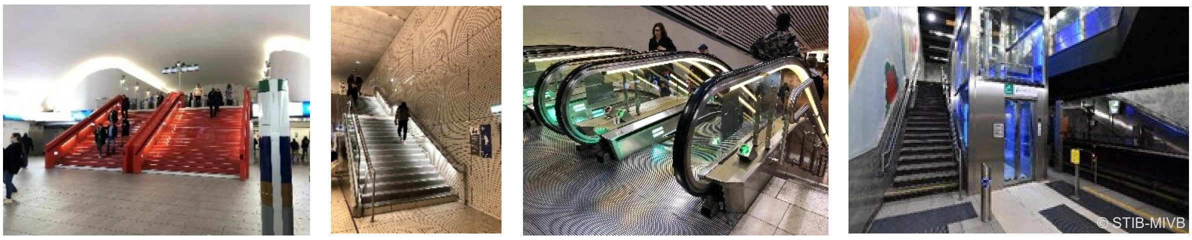

Figure 8. *From left to right: stairs at Saint-Lazare station in Paris, escalator at Stockholm City station; lifts at Jacques Brel station, Brussels*

6. Connecting corridors, can also be the subject of light and sound art that contributes to the creation of identity. An immersive artistic installation by Tine Havelock Stevens and collaborators invites user participation, enriching the overall atmosphere with a sense of fluidity and shared experience (Figure 9).

Figure 9. *Installation by Tine Havelock Stevens and collaborators at a pedestrian tunnel connecting underground transport amenities in a metro station, Sydney*

7. The ticket validation area is a critical zone often considered at risk. Although the design of the surrounding area may be exceptional (Figure 10, left), the complete integration of access gates may be confusing for people with cognitive and visual impairments. That is why this area should be clearly marked using contrasting colours to enhance spatial legibility and supported by reinforced lighting that subtly indicates direction, thereby facilitating smoother and more intuitive wayfinding (Figure 10, right).

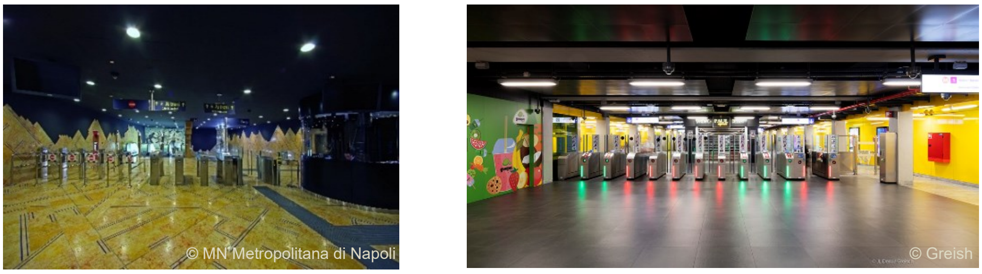

Figure 10. *Left: Toledo metro station, Naples. Right: De Brouckère metro station, Brussels.*

8. High visibility and spatial legibility through well-designed light provide a sense of reassurance (Figure 11, left and centre). At the Shuman station, top skylights allow daylight to reach platform level, with brightness regulated by sensors that adjust to outdoor light intensity (Figure 11, right).

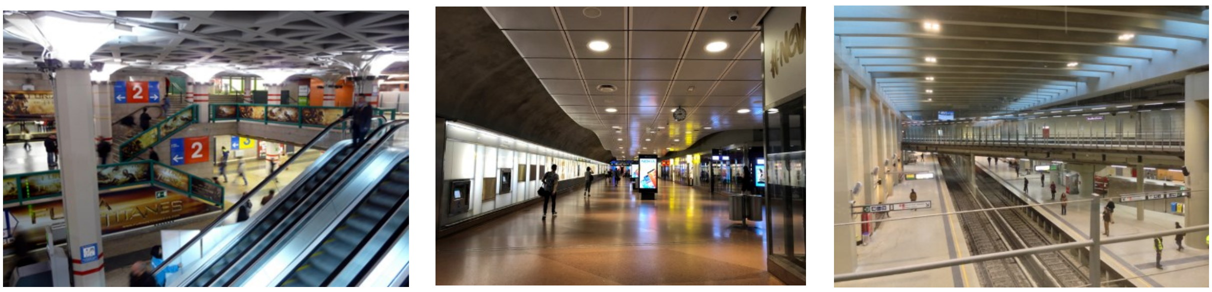

Figure 11. *From left to right: Metro station, Madrid; Stockholm City Station; Schuman station, Brussels.*

9. Enhancing the visibility and legibility of user information, particularly safety signage, through the strategic use of lighting, geometric forms and adhesive materials is a highly important component of inclusive design. Such approaches ensure that guidance and safety information remain accessible to all users, regardless of their sensory or cognitive abilities (Figure 12).

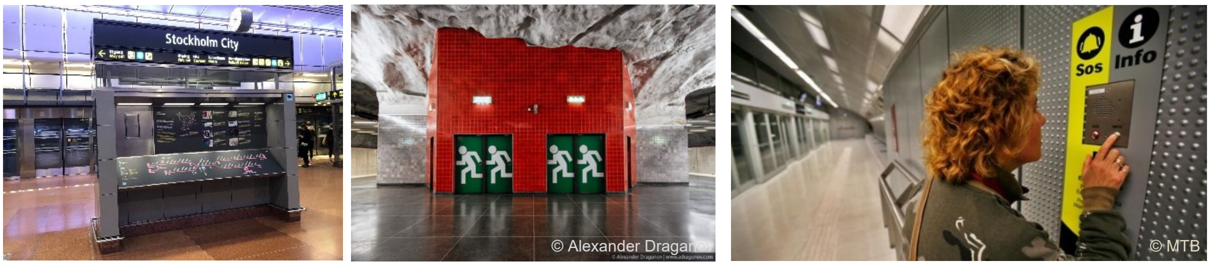

***Figure 12**. Left: Information point at Stockholm City station. Centre: Stockholm Underground. Right: SOS device, Barcelona.*

10. An insightful example of working with light and materiality is found in the work by Kimsooja at the Mairie de Saint-Ouen station in Paris (Figure 13). By integrating light diffraction into the design, the artist creates a sensory and poetic experience. As light interacts with the glass walls, it splits into vibrant colour spectra, transforming the space into a dynamic, ever-changing artwork that offers users a unique immersive experience, with perceptions shifting in relation to their movement.

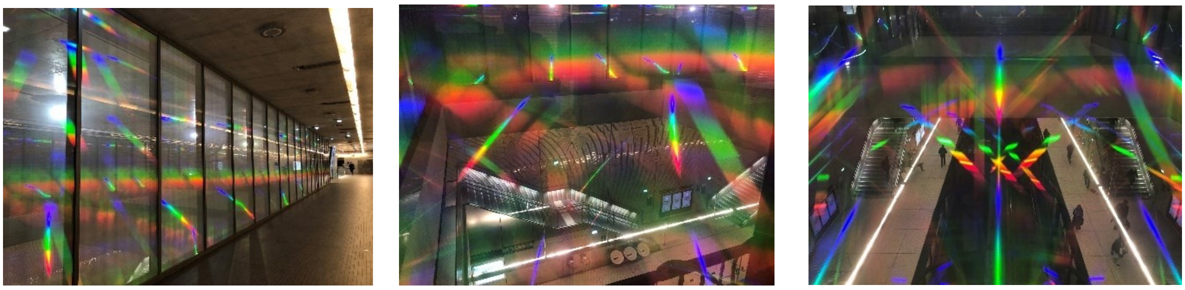

***Figure 13.** Installation by Kimsooja at Mairie de Saint-Ouen station, Paris.*

6. CONCLUSION

A lighting charter, when conceived as a structuring rather than a constraining framework, proves instrumental in user-centric design. It encourages interdisciplinary collaboration among architects, engineers, designers, stakeholders, and expert users, while remaining sensitive to context, sustainability, and maintenance. Instead of imposing uniform solutions, it provides coherence and usability while leaving space for creative interpretation and atmospheric expression.

Effective lighting design enhances spatial legibility, facilitates wayfinding, and reinforces the sense of security, particularly in underground environments where the absence of natural light poses significant challenges. Transitions between surface and subterranean spaces are always critical: carefully orchestrated lighting gradients support visual adaptation, facilitate orientation, and mitigate discomfort. Tools such as mock-ups and on-site light mapping, measuring both illuminance and luminance, allow evidence-based decision-making, ensuring that technical performance aligns with perceptual quality. Luminance offers a closer correlation to human perception and feedback, and thus serves as a more reliable measure of user experience.

Beyond functionality, lighting enriches architectural narratives and subtly guides movement through space. Variations are not limited to explicit spatial functions but are used to create sensory depth, stimulate affective engagement, and enhance the immersive qualities of underground environments. In this regard, lighting contributes to the perception of time, spatial and functional hierarchies, and bodily experience, activating both physical and emotional dimensions of inhabiting space. While it does not alone define the atmosphere of a place, it remains a fundamental component in understanding and shaping its overall quality.

Crucially, lighting should complement rather than dominate architectural forms, except where artistic expression intentionally takes precedence. This dual role, technical and aesthetical, positions lighting at the intersection of engineering precision and design creativity.

Designing for underground environments requires a holistic approach that integrates natural and artificial sources in relation to spatial and temporal dynamics. Factors such as placement, intensity, direction, ambient and intended effect must be considered not in isolation but as part of a user-centric design strategy that directly impacts well-being, safety, universal accessibility, and urban inclusion. In this sense, lighting is not a secondary technical component but a strategic lever for healthier and more sustainable urban spaces.

Ultimately, the quality of lighting, together with spatial clarity and architectural legibility, forms the foundation of accessible, fluid, and inclusive underground environments. By enhancing user-centric design, encouraging public space appropriation, and reinforcing attractiveness of public transportation, lighting emerges as a pivotal agent in advancing urban continuity and the quality of human experience.

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*Rem. 2 : Personal translation from French to English with the assistance of AI tools.