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Abstract:

This project explores how visually impaired people perceive light and how does it shape their everyday experiences. It tackles the issue of urban lighting and the lack of adaptation to the visually impared. It adresses the lack of research done on the topic and aims to contribute to narrowing that discrepany. Focusing on methodology and humanistic approach it researches how different senses impact perception of the space and how lighting can be incorporated into that. The focus is placed on train stations as a common sense of stress in everyday lives. The goal of the project is to gain understanding by exploring new methodologies. To offer a different approach to the design of urban lighting, and to create a solution with humans as the users at the centre.

The senses of light

Designing urban lighting for visually impaired

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1. INTRODUCTION

1.1 PROJECT DESCRIPTION

According to European Blind Union (EBU) “there are estimated to be over 30 million blind and partially sighted persons in geographical Europe”. Vision impairment or blindness are more prevalent in people above 50 (World Health Organization, 2023). “From 2020 to 2050, the number of people with vision impairment could triple due to the combined action of ageing and population growth. Among the 253 million people who live with vision impairment around the world, the vast majority, 217 million, have moderate to severe vision impairment, that is, they are partially sighted.” (Laurìa et al., 2018) Yet most research studies, as I have come to find out throughout doing this project, focus on indoor lighting for the visually impaired. And while that is an equally important topic and a field of study, one can not help but wonder why such a discrepancy in research exists in this field. Although I am certain it is not intentional, the after effect of this is the further marginalization of “non-typical” people in our society. Typical here referring to being able bodied and not impaired in any significant way. “The urban built environment continues to impose restrictions on people with diverse impairments, including those with vision impairment, limiting their opportunities for social participation and mobility.” (Mattsson et al., 2020) Although a subliminal fallout, the underlying message is that it does not matter if the urban environment is fit for them. That they don’t need to exist in the outside world or that their comfort is subpar. What an irony that public spaces are in fact not meant for all of the public. Why is it that the world we design as a society is not adapted to a large portion of that very society?

I do not have an answer to this, nor will this study provide one. Instead, I aim to reduce the aforementioned gap in research. This project will focus on the perception of lighting in VI (visually impaired) individuals. how we can better design inclusive urban outdoor spaces.

Everyday commuting is a prominent source of stress for many. This issue is a widely recognized and researched pain point. A biproduct of urbanisation, life in cities is accompanied by daily travel to and from work. City residents are at a 40% higher risk of depression compared to those living in rural areas. (Bhugra et al., 2019) Issues such as pollution and lack of green surfaces contribute to this fact. However, public transportation, specifically via railway, is another prominent contributing factor. (Avila-Palencia et al., 2018)

Studies indicate that poor perceptual-physical station design is one of the key sources of commute related stress. (Litman, 2014) Evidently, there is a need to improve their design and the very way we approach it. When returning from a workday in dark hours of the day, exhausted and longing for the comfort of their home, nobody wants to spend unnecessary time scrambling to find the right exit to a train or deciphering the layout of the station. Lighting may not seem like it

carries a vital role in wayfinding, but I hope that throughout this project I can show just how much of a difference it can make and how helpful it can be. “The word wayfinding ‘encompasses all of the perceptual and cognitive tasks that enable travellers to find their way to destinations’” (Laurìa et al., 2018) Both to VI and sighted people, lighting in wayfinding largely affects the perception and experience of space.

Therefore, I have taken this as the centre focus for my contribution to research on urban lighting for VI. This project will explore a new approach to how we think about lighting, specifically in the context of visual impairment. But I believe that the final design adds value not only to VI but to sighted individuals as well.

Summed up in a short sentence The scope of this thesis is to research the perception of lighting in VI individuals and rethink the way we design lighting for them in urban context of public transport stations.

1.2 INSPIRATION FOR THE PROJECT

As is the case with most projects, I chose the subject based on personal interest which started forming few months prior to the development of this thesis. It was during the tenure of my internship, which is what preceded this thesis. I was working at Vega, a well-known concert venue in Copenhagen, as a light designer and technician. Considering my prior education within lighting design, my knowledge thereof comprised of a primarily architecture centric focus. Thus coming into an entirely different environment that is the entertainment industry vastly changed my perspective of lighting.

Light was no longer this mystical static entity with a mind of its own that once illuminated beams and arches. Or something that exists only on a working surface and follows standards. As if it gained a new dimension, light was suddenly palpable. Pliable and able to be moulded into anything one could imagine. It gained momentum, expression and weight. Instead of following guidelines, it broke rules; deliberately using discomfort and glare as a virtue rather than a flaw. What if architectural lighting could also follow the same principles?

Often-times we would have members of the audience who for one reason or another had a different experience to what is considered typical. Vega is incredibly adept at accommodating everyone and never was this an issue. But this led me to start thinking about how different people’s perception of the same experience can be. Something as simple as having an eye prescription and forgetting your glasses can alter the way you see the show. Sitting in a wheelchair and having a different field of view surely must affect the show’s perception. I for one, never crouched to see how the lights look from a lower angle until then. Or a higher one for that matter, for all the tall people in the audience. What if we deliberately designed solutions relating to different perceptions?

The newfound outlook on light along with wanting to understand different perceptions grew as interests for me and are what outlines the approach to this thesis.

2. THEORY

2.1 DEFINITIONS

Visual impairment and blindness are terms that often get used interchangeably. In everyday conversation especially they are often even used wrong. For the sake of better comprehension and to help define what this project is about, I will clarify what I mean when using these terms.

According to the International Classification of Diseases (ICD), there are six defined categories to classify visual disturbances. As shown in figure 1. These are used to define legal definitions of blindness.

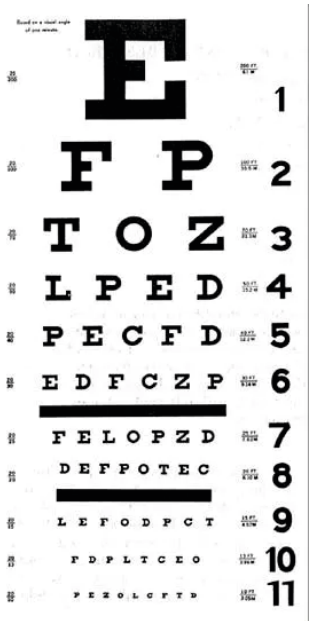
figure 1
definitions of blindness and visual impairement (CDC, 2019)

Category	Presenting distance visual acuity	
	Worse than:	Equal to or better than:
0 Mild or no visual impairment		6/18 3/10 (0.3) 20/70
1 Moderate visual impairment	6/18 3/10 (0.3) 20/70	6/60 1/10 (0.1) 20/200
2 Severe visual impairment	6/60 1/10 (0.1) 20/200	3/60 1/20 (0.05) 20/400
3 Blindness	3/60 1/20 (0.05) 20/400	1/60* 1/50 (0.02) 5/300 (20/1200)
4 Blindness	1/60* 1/50 (0.02) 5/300 (20/1200)	Light perception
5 Blindness	No light perception	
9	Undetermined or unspecified	
	* or counts fingers (CF) at 1 metre.	

The numbers used to define these are representative of what the person can see in comparison to regular vision. Therefore, a measure of 3/18 means that what perfectly sighted see at the distance of 18 meters, this person sees at the distance of 3 meters.

When defining visual impairments, there are two factors that are taken into account; visual acuity and field of vision.

figure 2
Snellen chart (Snellen, 1962)



"Visual acuity the relative ability of the visual organ to resolve detail that is usually expressed as the reciprocal of the minimum angular separation in minutes of two lines just resolvable as separate and that forms in the average human eye an angle of one minute" (Merriam-Webster, 2019) In other words, it is a measure for how sharp one's sight is and how accurately visual details can be distinguished.

Visual acuity is measured using a Snellen chart (figure 2- Snellen 1962) which uses the same unit of measure to express the results. Perfect vision would be being able to read the letters on the lower line from a distance of 6 meters. Legal blindness is defined as not being able to see the first line of the chart, the letter E, even with correction. Severe visual impairment would be not being able to see the third line under the same conditions.

The other factor taken into account when determining the definition of blindness is field of vision. This is referring to the amount of functioning peripheral or central vision a person has. (figure 3) In terms of this, legal blindness is defined as having a field of vision of 20° or less.

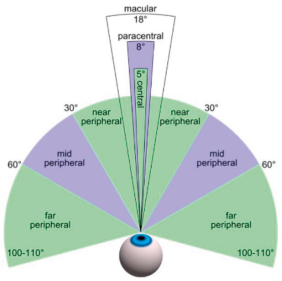


figure 3
field of vision (pediatric epilepsy surgery aliance , 2023)

In determining level of visual impairment, the amount of light a perception a person has plays an important role. A common misconception is that blind people see darkness, however most have some degree of light perception. A common way to describe the amount of vision someone has is to refer to the ability to use said vision in everyday life, namely for reading print and maneuvering through space. A less strict definition is to say that those with visual impairment are still able to use their sight for reading print and manoeuvring through space to a varying degree.

For this project, when referring to VI persons, I am following the legal definition of visual impairment, while the latter, more common one also applies.

2.2 CURRENT STANDARDS FOR TRAIN STATIONS

I looked at available guidelines and standards for lighting of train stations specifically in Europe. PRM TSI (Technical Specifications for Interoperability – Persons with Reduced Mobility) is a document summary of Commission Regulation (EU) No 1300/2014. The document was published in 2014. It outlines technical specifications regarding accessibility of European Union's rail. It encompasses persons with disability and reduced mobility.

In terms of lighting it states some specific guides related to the amount of lux, contrast etc;

- "Illumination to a minimum of 100 lux at floor level from the accessible building entrance to the platform access point." "Main entrances, stairs, and ramps should have a minimum of 100 lux at floor level. If artificial lighting is necessary, it should be at least 40 lux above ambient light levels and have a cooler color temperature." (ERA, 2014)
- For platforms and external area – "minimum average illumination of 20 lux, with a minimum of 10 lux at floor level." (ERA, 2014)
- "Locations requiring detailed information should have lighting that is at least 15 lux higher than adjacent areas and may have a different color temperature." (ERA, 2014)

Another guideline that is publicly accessible is Design Standards for Accessible Railway Stations. Developed for use in Scotland by the Department for Transport (DfT) and Transport Scotland in 2008.

It recommends lighting to be even and consistent throughout the station, and avoidance of any possible glare. (UIC, 2008)

It refers back to an earlier version of the PRM TSI in some of its' guidelines.

Interestingly, it favours the use of daylight when possible "Wherever possible, it is recommended that public buildings are designed to make use of natural lighting, although care should be taken to minimise glare and strong reflections from surfaces" (UIC, 2008)

Some lux levels are also defined for specific scenarios. "Steps and stairs should be well lit, without glare. It is recommended that lighting levels increase to 150–200 lux and that the transition should be smooth." (UIC, 2008)

It also highlights the better colour rendering properties of white light but does not strictly condemn its use.

In summary, both of these standards are slightly outdated, but have good intentions. The Scottish one especially does a good job of describing how the lighting should be without focusing on reaching specific levels too much. Both of these recommend uniform luminance which is something I will touch upon in the next subchapter.

2.3 UNDERSTANDING PERCEPTION

There are many misconceptions when it comes to our ideas of blind and visually impaired. I have already mentioned how most assume that all blind people see nothing but darkness. Perhaps related to that, the idea that blind people can visualize things seems contradictory or absurd even. What we fail to realize is that "to see does not only require functioning eyes and optic nerves but also functioning brain structures," (Cattaneo and Vecchi, 2011, p. 1). Mental imagery is just as much a part of seeing as are eyes. Just because one of those does not function, does not mean that the other does not either. The reason behind this was addressed by Pallasmaa in his book The Eyes of the Skin; "In Western culture, sight has historically been regarded as the noblest of the senses, and thinking itself thought of in terms of seeing." (p. 17) If we primarily view thinking as seeing, then a blind person would have trouble thinking. This very simple critique of our flawed logic can not be reiterated enough.

Georgina Kleege, a blind author and professor, does a fantastic job of describing this throught her own experience – "One night I was washing potatoes for dinner. I was trying to find words to express the look of the running water and the sheen of the chrome faucet. I was having trouble separating what I was seeing from what I was feeling – the slightly fizzy stream of warm water – and what I was hearing – the slush of the water over the faint gurgle of the drain. I could tell that the sounds were influencing the image." (p. 6)

What she describes is how other senses work together to fill in the picture on a subconscious level, as she does not actively distinguish between which sense is responsible for which input. She specifically points out the sheen of a chrome faucet. To sighted people this is a purely visual experience affected by how light is refracting from an object. As mentioned previously, most blind people have the ability to see light, and so does the author. But the way she describes it alongside all the other senses poses, to me, a question of can light be felt, and not just seen? Does light have a plasticity?

Another common misunderstanding we have about blind and visually impaired (BVI) is that as a result of their lack of sight, their other senses develop to become superior. The book Blind vision, The Neuroscience of Visual Impairment gives an overview of research and findings on the differences in senses in BVI compared to sighted individuals.

Authors Cattaneo and Vecchi highlight the discrepancies, inconclusiveness and outright varying results in research done on the same topic. In some research blind outperform sighted people, and in some they perform same as sighted. They raise the question of if blind truly did have heightened senses, shouldn't they consistently outperform sighted people.

In relation to the sense of hearing. They summarized the findings of several studies; "Research comparing congenitally blind and normally sighted individuals didn't show significant differences in elementary auditory sensitivity, such a frequency" (p. 15)

While at the same time summarizing the findings of studies with a different

outcome; “An auditory perceptual enhancement in early blind individuals is likely to be reported in more complex auditory perceptual tasks.” (Cattaneo and Vecchi, 2011, p. 15) They provide an example of a complex task from the study where the participants were asked to discriminate between the intensity of tones presented in one ear while simultaneously hearing unrelated sounds in the other ear.

Overall, they state how it is hard to compare the studies and outcomes because of how much the measured activities differ. And additionally, how most of the time these studies attempt to isolate the senses or the perception to the point where it does not prove anything as it would have no application in real life. Furthermore, they point out that “Enhanced auditory capacities of the blind depend on their usually greater musical experience, rather than to differences related to vision loss.” (Cattaneo and Vecchi, 2011, p.15)

The same was found to be true for other senses as well. In some complex tasks, congenitally blind will slightly outperform the VI or sighed individuals. But to say it is due to some abnormal sensitivity of their senses would be false. Instead, it boils down to the setup of the tasks and whether they’re more tailored to the perception of sighted or the perception of BVI.

Not only is there a misconception in how blind people have superior senses, but there is also a misconception of how they use said senses. “Too often programs assume that the point of tactile exploration is to recognize forms through tracing their outlines. I have found that the most rewarding touch tours engage the full spectrum of touch sensation – texture, temperature, resiliency as well as form.” (Kleege, 2018, p. 11)

In her book, Kleege heavily references the hypothetical blind man, or the Hypothetical as she calls him, and compares her real life experiences to those imagined of the Hypothetical. “Unlike the Hypothetical, they [blind people] do not feel themselves to be deficient or partial – sighted people minus sight – but whole human beings who have learned to attend to their nonvisual senses in different ways.” (p. 28)

The hypothetical is a philosophical exercise that was first proposed by Descartes. He had inviting the reader to imagine life as a blind man. Relating blindness to a sighted person walking around in the night using a stick out of necessity to guide yourself and to recognize the difference between trees, mud, water or sand. (1637)

She goes on to criticise, rightfully so, that “Descartes description reflects a basic misunderstanding. He imagines that the blind man uses a stick to construct a mental image of his surroundings, while his other senses, not to mention memory and cognition, remain inactive.” (Kleege, 2018, p. 15) She later clarifies how “The cane is more of an obstacle detector than a tool to map the environment.” (p.16) And how in Descartes’ theory the hypothetical would certainly first be able to tell if he was walking on sand, mud in water or on grass simply by walking on it, not by poking the ground with a stick.

Seeing her point out the flaws with all the thought exercises involving the hypothetical makes the reader wonder how such a silly misconception even came about. And how surely nowadays people must know better. Yet the reader is left appalled as she brings examples after example of similar misinformed ideas in modern research and her own encounters.

In Blind vision, the authors bring up a crucial concept for understanding BVI perception. “Haptic perception refers to the combined use of cutaneous and kinaesthetic sense.” (Cattaneo and Vecchi, 2011, p. 29) Meaning it encompasses

active motion in forms of touching in addition to the tactile sense being activated. Feeling the wind on one's skin would, for example, not be a haptic perception. But holding a handrail while walking down the stairs would.

What I think most people forget when thinking about the tactile sense is that it does not need to be haptic, or active. People do not need to touch something to feel things on their skin. The wind, sun, temperature of the air can all be felt without active movement.

"The hand is one of the many organs of touch perception and enumerates at least three different aspects of touch sensation that are meaningful – texture, temperature, and vibration." (Kleege, 2018. 24)

A few interesting studies that Cattaneo and Vecchi point out are those relating to how blind people and sighted people perceive space. "Sighted individuals would by default activate an external spatial reference frame system for sensory perception and action control." (2011, p. 45) The study asked participants to remember the order in which varying tactile stimuli were delivered to their left and right hands. The same task was repeated with hands crossed. Blind individuals outperformed in the case of crossed hands. What happened is that sighted individuals assigned the stimuli to left or right hands to better remember them. In other words they utilized a spatial reference frame which then acted against them when their hands were crossed as it took more effort to use this system.

The blind significantly outperformed the VI and sighted people. Not because of superhuman tactile or auditory abilities but because of the way they form the mental image of the space around them. "Mapping of sensory inputs into external coordinates is not innate, but occurs as a consequence of visual input" (Cattaneo and Vecchi, 2011, p. 48)

Related to this perception of space, the book explores studies that investigated egocentric and allocentric spatial representations.

"In egocentric spatial representations, space is represented with reference to the observers body; if the subject moves, the spatial representation needs to be updated accordingly" (Cattaneo and Vecchi, 2011, p. 115) "Allocentric spatial representation is generated regardless of the individual's position. They may be centred around a specific object or built with reference to a virtual point of view." In other words, allocentric is like looking at a map while egocentric is like using street view.

Kleege brings up an interesting occurrence from a study looking into similar phenomena "Some researchers have sought to understand how blind people conceptualize space and map their environment. [...] In one instance blind children were required to follow a path by holding onto a rope that marked it. At each turning point there was some sort of a prize. Afterward, they were asked to draw a line showing the route and indicating the sequence of the prizes. One child drew a more or less straight line, indicating what the prizes were." (p. 38) The researchers even prompted the child to try to revisit her drawing and to really consider the corners and turns. To the researchers' seeming disappointment, the child did not change her answer.

What had happened is that the blind girl used an egocentric representation of space, whereas the researchers were thinking only in allocentric terms. Other studies likewise show that blind individuals tend to rely more on the egocentric representation. (Cattaneo and Vecchi, 2011)

Perhaps it is due to this constant misunderstanding that Kleege said; “Ultimately the goal of so much of the modern research on blind subjects seems to have very little practical applications to education or cultural enrichment.” (p. 40)

I believe the reason for this is the lack of understanding people often have for those unlike them. This does not only apply to BVI of course. “One of my nephews was asked to draw a picture of himself at school. In his picture there was a circle. To the right of this circle there were two feet, and to the right of these there was a hand with all five fingers extended with a circle, smaller than the first, right above it. When asked my nephew explained that it was a picture of him running to catch a ball.” The picture was intended to be read from left to right, as a comic. The teacher viewing this picture became concerned that what to her seemed as a disjointed drawing, reflected some sort of a defect or delay in cognition.” (Kleege, 2018, p. 41) This teacher, much like the researchers with the line drawing and like Descartes with his Hypothetical blind man and seemingly a lot of the society, fails to understand the existence of perspectives other than their own.

2.4 LITERATURE REVIEW

The previous chapter focused on understanding the perception of what it means to be visually impaired and blind. This chapter will focus on the current research being done in the field of lighting design in relation to BVI. Lighting plays a crucial role in daily lives of visually impaired. “People with moderate or severe visually impairment rely primarily on their remaining vision to orient themselves in their surroundings.” (Hauck et al., 2019) Lighting has a considerable impact on their vision.

QUALITIES OF LIGHT

A significant portion of the research has been dedicated to understanding different qualities of light and how they impact VI. “Unfavourable lighting conditions can further hamper this remaining vision.” (Hauck et al., 2019) In general “reduced visual performance may involve one or more of the following conditions: reduced contrast sensitivity, restricted field of vision, adaptation problems, increased sensitivity to glare, impaired colour vision, reduced visual capacity and slower processing of visual information.” (Hauck et al., 2019)

Hauck et al. specifically highlight glare, “Some 75 % of the surveyed participants with visual disabilities identify reflected glare (as on glossy floors) as disturbing or very bothersome”, and contrast, “As compared to people with normal vision, the contrast sensitivity of the visually impaired participants in our study was significantly reduced. Thus, higher minimum contrast levels would be required for this population.”, as two qualities of light with a significant impact on VI individuals. Studies persistently show that increased contrast benefits the everyday environments of visually impaired. “While visiting the respondents, it is interesting to observe that enhanced contrast to help or as a reason for discomfort is not always consistently recognized. The preliminary findings illustrate that many respondents often preferred a luminance pattern with a large ratio from the highest to the lowest luminance. These luminance patterns resembled patterns that people with normal vision prefer, where the private home has isles of light with high luminance to enhance a specific functionality like the dining table, reading area, etc.” (Mathiasen et al., 2024) Contrast does not only relate to contrast in luminance. It also refers to contrast in colour. “There is a greater visibility – in equal contrast conditions – of light objects on a dark background (positive contrast) as compared to dark objects on a light

background (negative contrast)" (Laurìa et al., 2018)

"There is a close relationship between contrast and uniformity," considering these findings related to contrast it makes little sense that "uniformity seems to be a standard aim in public lighting" some interviewees agree that uniformity is beneficial as it show all of the space equally. (Radicchi and Henckel, 2023) The authors also offer another interesting factor of contrast, further pointing out it's qualities for use in public lighting; "Pools of light or intentional patterns of shadow or colour facilitate movement and directionality. The pedestrian can subliminally "count" the number of lines or pools to understand better the distance yet to go, which in turn elevates a sense" (Radicchi and Henckel, 2023)

Other qualities of light such as intensity tend to be more individualized. "Visual impairments affect the role of light and how it is perceived. For some visually impaired participants, it was a matter of quantity: the more illumination, the higher their visual function. The feeling of needing more light was a recurring narrative in the empirical material. Insufficient lighting could cause eye strain and discomfort. For others, bright light blurred their vision. Describing the experience of light was difficult in some situations: "It is a little too sharp... and makes it a little too blurry... oh, what to say..."."(Borgestrand Øien, 2021)

LACK OF OUTDOOR RESEARCH

As mentioned in the introduction, most research I encountered on BVI and lighting was concerning indoor lighting and lighting in their own homes. I was by no means the only one to notice this discrepancy. In their study exploring the Artificial Light at Night for Pedestrian Visual Diversity, the authors recognize the lack of consideration for VI. "The failure to sufficiently take into account visual impairments in the integrative light-planning discourse is remarkable" (Radicchi and Henckel, 2023) They recognize this problem and go on to raise it as a question in conversations with professionals in the field. "Overall, the results showed that there is a scarcity of studies and projects that address the needs for artificial lighting among visually impaired pedestrians at night in public spaces, thus revealing a burning gap in knowledge which requires urgent addressing" (Radicchi and Henckel, 2023) The answers which they received were varying, but insightful. "The most important reasons derive from the complexity and variety of the lighting sources in pedestrian settings—sources that are underregulated and managed by different actors—and the more erratic, or less directional, movement of people in public spaces," (Radicchi and Henckel, 2023) There is never a simple answer, and seemingly many factors come into play to create this discrepancy in research. Some professionals point out how VI make up only a small segment of the population; "Many different visual impairments that would entail different and specific requirements for supporting a relatively small segment of the population, thus making this a minority problem that cannot be easily regulated." (Radicchi and Henckel, 2023) They also state how due to different individual needs of VI it would be challenging to find a one-fits-all solution. Of course, money is always involved in the conversation as well. "...obtain funding for and conduct research into indoor settings (such as the workplace or the home) where the variables are more controllable and, hence, solutions are more easily available than in public spaces" (Radicchi and Henckel, 2023). It all boils back down to how it is easier to conduct studies related to indoor lighting for VI. Continuing to choose the path of least resistance "In fact, in indoor settings—e.g., in workplaces and even more so in private homes—it is much easier to care for the specific needs of visual diverse people, because the lighting can be personalized more easily." (Radicchi and Henckel, 2023)

From the reasons given it is clear that they are already thinking in solutions rather than in research. A construction they place on themselves, perhaps purposefully,

to avoid dealing with challenging topics. They are already assuming that the result of the research would be that everyone selects a different luminaire that works best for them and they are left with impossible amounts of wishes to incorporate into the solution.

But not all grim. “In Munich, a lighting study for the main train station conducted by the Deutsche Bahn involved visual diverse pedestrians in the planning process for identifying appropriate specifications for the luminaires.” (Radicchi and Henckel, 2023)

FOCUS ON LUX LEVELS

Another tendency I noticed in the research, is that a lot of it focuses on standards and light levels. “For decades, the planning of artificial light at night has mainly been approached as a technical issue that focuses on providing sufficient light levels for vehicular traffic and pedestrians in cities.” (Radicchi and Henckel, 2023) As stated before, needs regarding amount of light are highly individualized. “However, it has often been considered as a quantitative measure, where different diagnostics or impairments require different lux levels and result in references to special lighting and assistive tools.” (Borgestrand Øien, 2021) This focus on quantitative data feels misplaced in this use case. As Mathiasen points out it is best to keep vague recommendations of lux levels or abolish them from guidelines altogether. “Extra light on task areas can be helpful to some, but to others, it creates discomfort. Therefore, it also makes sense that all four guidelines for visually impaired people underline that it is highly individual how much light they need to feel comfortable and thus has vague recommendations or ultimately leaves out any recommendations for concrete lux level.” (Mathiasen et al., 2024)

SMART TRAFFIC AND NEW TECHNOLOGY

On a more positive note, there are some interesting advancements amongst the research. Smart traffic lights with various built-in sensors and features with the possibility to inform pedestrians of their current location in the city. Integration with mobile phones to allow for more features etc. (Theodorou et al., 2022) Motion detection lighting to provide additional light on demand is another example of potential future solutions. (Radicchi and Henckel, 2023)

WALK ALONG INTERVIEW / HOME VISITS

Borgestrand Øien et al. use an interesting method in their research approach. Considering the authors’ diverse backgrounds in architecture and lighting, they were focused on the temporal flow through space and movement in their approach to analysing home environments. “Knowing that our analytical framework would focus on the role of the home environment and the lighting conditions within the interactions of everyday life, an objective of our design of the interview guide was that it should guide a spatial trajectory from entering the participant’s home when seated in a traditional interview-setting or walking across the different spaces in a walk-and-talk interview.” (Borgestrand Øien et al., 2024) In their walk along interviews they would follow VI participants around their homes as they went through rooms describing their usual routines and obstacles. “In the interviews, we would ask about specific activities within the home as well as transitions between activities or the act of moving across the space—or zooming in and out between a focused activity and orientating. Furthermore, exterior settings close to the home would be another transition of relevance. Therefore,” (Borgestrand Øien et al., 2024)

2.5 FINDINGS

To summarize this chapter, in terms of perception and senses “even a severe but not complete visual deprivation may itself result in auditory and tactile acuity gains.” (Cattaneo and Vecchi, 2011, p. 141) Meaning that the blind and visually impaired do not have superhuman senses but instead are more adept to using them in different ways than sighted individuals. Furthermore “Low vision does not prevent the capacity to generate appropriate visual representation of an environment.” (Cattaneo and Vecchi, 2011, p. 144) The end result of what sighted compared to VI perceive is similar or even the same. VI can be equally aware of the space around them as sighted individuals. The difference is in the way the perception formed.

Most research related to lighting and VI focuses on indoor lighting for various reasons. However some findings from that research can be useful in outdoor lighting scenarios as well. Knowing that glare and contrast are two qualities of light that affect VI will be of valuable insight. And methodologies such as walk along interviews are just as applicable outdoors as they are indoors.

Overall, there is a strong focus on the quantitative measures in research and a gap for more qualitative, user driven studies, which is what this project will aim to be.

3. RESEARCH QUESTION

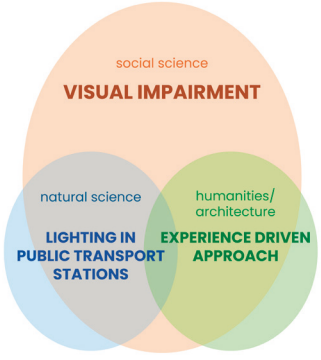
Following the findings from the last chapter, the research question of this project is defined as follows:

How can we design lighting in public transport stations for visually impaired using an experience driven approach?

3.1 CRITERIA

The research question can be broken down into three key components. By defining these I will set the criteria for the scope and success of this research project. The three components, or the spheres can each be correlated to one of the three sciences; natural, social or humanities/architecture. Often these will overlap and influence each other. In this chapter I will explain their significance and use in this project. In the context of this research, they are not equal so to speak. What I mean by this is that although I correlated the spheres to sciences. I will look at lighting in stations and experience driven approach within the context of visual impairment. As represented in figure 4.

figure 4
relation of sciences in this project



Firstly, lighting in public transport stations. As mentioned in the introduction, commuting and navigating stations of public transport are one of the most common daily stressors of urban environments. As I have come to learn through this master's programme, lighting can strongly influence wayfinding and the way we perceive a space. Yet looking at the guidelines and papers written about lighting in stations, it focuses mostly on numbers and reaching standards. Why has the sociological aspect not been taken into account here? Instead the focus was almost entirely on natural sciences. Which is why I placed it within that sphere.

My hypothesis is that rather than following standards, using qualitative knowledge from studies done with human input to design with intention will aid with wayfinding.

From that, the criteria of success is improved wayfinding.

Another reason for putting this subject into natural sciences is for the methods that will be used to assess the current qualities of lighting in the station. For this, I will conduct a luminaire analysis, illuminance map, HDR imaging and material analysis.

Overview of all the criteria is shown in figure 5.

Criteria

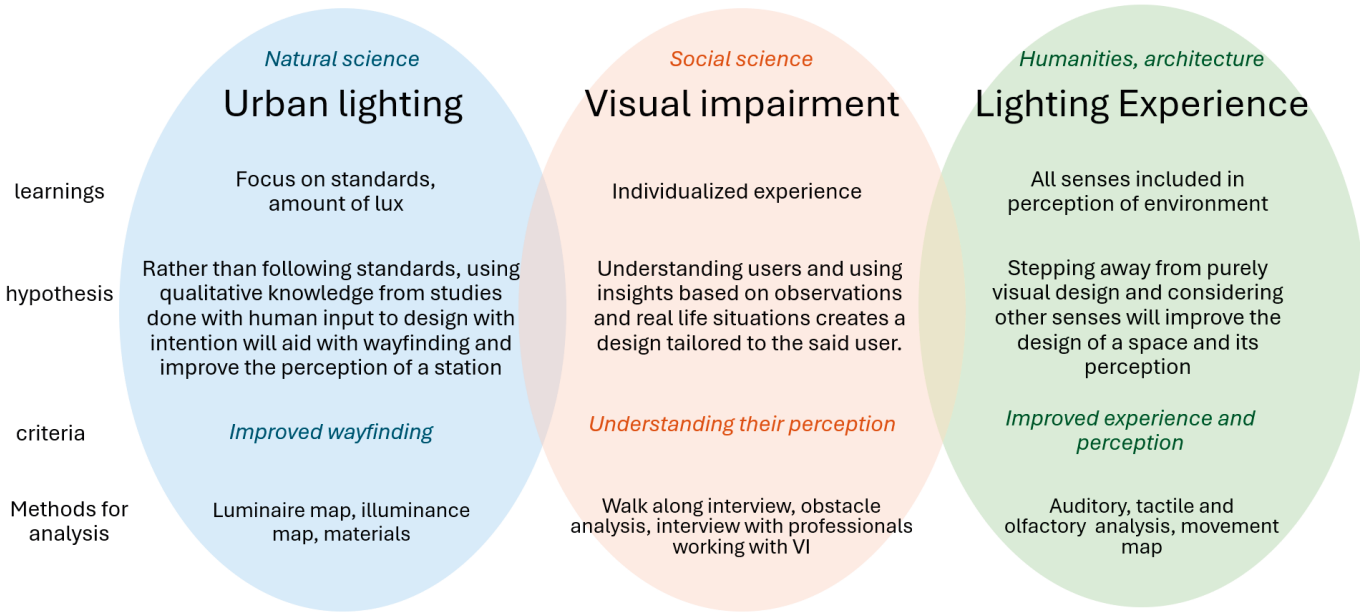


figure 45
diagram of hypothesis and criteria

The second sphere is related to visual impairment and understanding their perception. As mentioned before, this sphere is overarching and encompasses the two others. The main goal within this area of research is to understand the perspective of VI persons, their needs and the obstacles they face.

The hypothesis is that by understanding users and using insights based on observations and real life situations we can create a design more tailored to said user.

The criteria here is very simple as the goal of this part of research is to gain an understanding of their perception. As this is based on perception, it will be hard or even impossible to quantify to assess how fulfilled the criteria are. Therefore, I will state that the end goal of this part of the research is to be able to analyse a space and lighting through the lens of a VI person.

The methods I will be using here are heavily focused on interviews. Both interactive and static. I will be conducting a walk along interview with an analysis of the pointed out obstacles, and a classic interview with professionals working with the visually impaired.

Finally, in relation to humanities and architecture I want to use an experience driven approach in this project. Here I was inspired by reading Kleege's description of her everyday life. As I talked about in the previous chapter, the way she explains how all of her senses work together to form an image of her surroundings reminded me of Pallasmaa's critique of modern architecture. The idea that we have been too focused on the visual whereas we should have been including other senses as well. Rather than thinking only in visual sense, we should be considering the perception from other senses as well.

My hypothesis is that by stepping away from purely visual design and considering other senses will improve the design of a space and its perception.

Improved experience and perception being the criteria here.

As for the methods, I want to use something unconventional and slightly experimental. Which is why I put this in the humanities sphere. I want to conduct an analysis of the station focusing only on other senses, hearing, smell and touch. I'm excluding taste as I do not wish to know what a station may taste like. And as I deemed it to be the less relevant sense in this context as it would be highly individual, with a potential of being affected with trivial things like a person chewing on a piece of gum. I will also observe to create a movement map, which is a more traditional tool for understanding how a space is used in ways that are not strictly visual.

3.2 CHOOSING THE LOCATION

For the purposes of demonstrating the learnings from this research I find it necessary to choose a real-life location. Copenhagen has many stations of public transport; shortage thereof will not be the conundrum this project faces. The issue arises with choosing which one to focus on.

I wanted to focus on a station which has multiple modes of transport, but most importantly train. Throughout my own experience as a commuter within the city, I had selected three stations that I frequent and know fairly well and consider to be in need of improvement. Three that I consider to have a potential for a better lighting design implementation.

These three were: Flintholm station, Bus terminal and Dybbølsbro, and Nørrebro

station. All three being particularly stress inducing, for me personally, for various reasons. With Flintholm, I find it incredibly confusing to navigate. Considering the bus terminal is a newly built station, wayfinding from Dybbølsbro which it should be connected to is not clear in the slightest. And finally Nørrebro, although it is a smaller station, I cannot help but feel stressed using it. My suspicion is that the culprits are lack of zoning and the sea of bikes that is seemingly always washed up in front of the entrance.

Throughout interviews which I will talk about later, I have learned that the only times stations have a chance at being adapted to those with VI is either when they are being built, or with older stations that are outdated and currently being renovated.

Because of this finding I have decided to choose Nørrebro station as the location for my project. The station building was built in 1930 by the architect K.T. Seest (Historiskatlas.dk, 2025). Although the building has been under protection since 1992 (Historiskatlas.dk, 2025), renovations to the lighting especially are possible. Seemingly there is construction going on in the area of the station at the moment.

4. METHODS

I already briefly touched upon the methods that will be used in this project. Here I will expand on that bringing in the context of the location as well.

For analysis of the station and the current lighting I will use a combination of qualitative and quantitative analyses. The quantitative will focus on understanding the parameters of lighting while the qualitative will focus on understanding the perception of the space.

For the analysis of the users, in this case specifically VI users, I will use mainly qualitative methods in the forms of interviews; walk along and stationary. I will also analyse the obstacles at the station, this method could be classified as a mixture of quantitative and qualitative.

Based off of the results and findings I will formulate a test which will drive the final design. This test will consist of various scenarios which will be presented to and discussed alongside individuals with VI. The goal here is to gain firsthand empiric data on the perception of different aspects of lighting in a controlled environment.

5. ANALYSIS

5.1 NATURAL SCIENCE

I will start off the analysis of the station with quantitative measures. The goal is to understand the current lighting, it's advantages and shortcomings. The area of this project has been mapped out in figure 6 below.

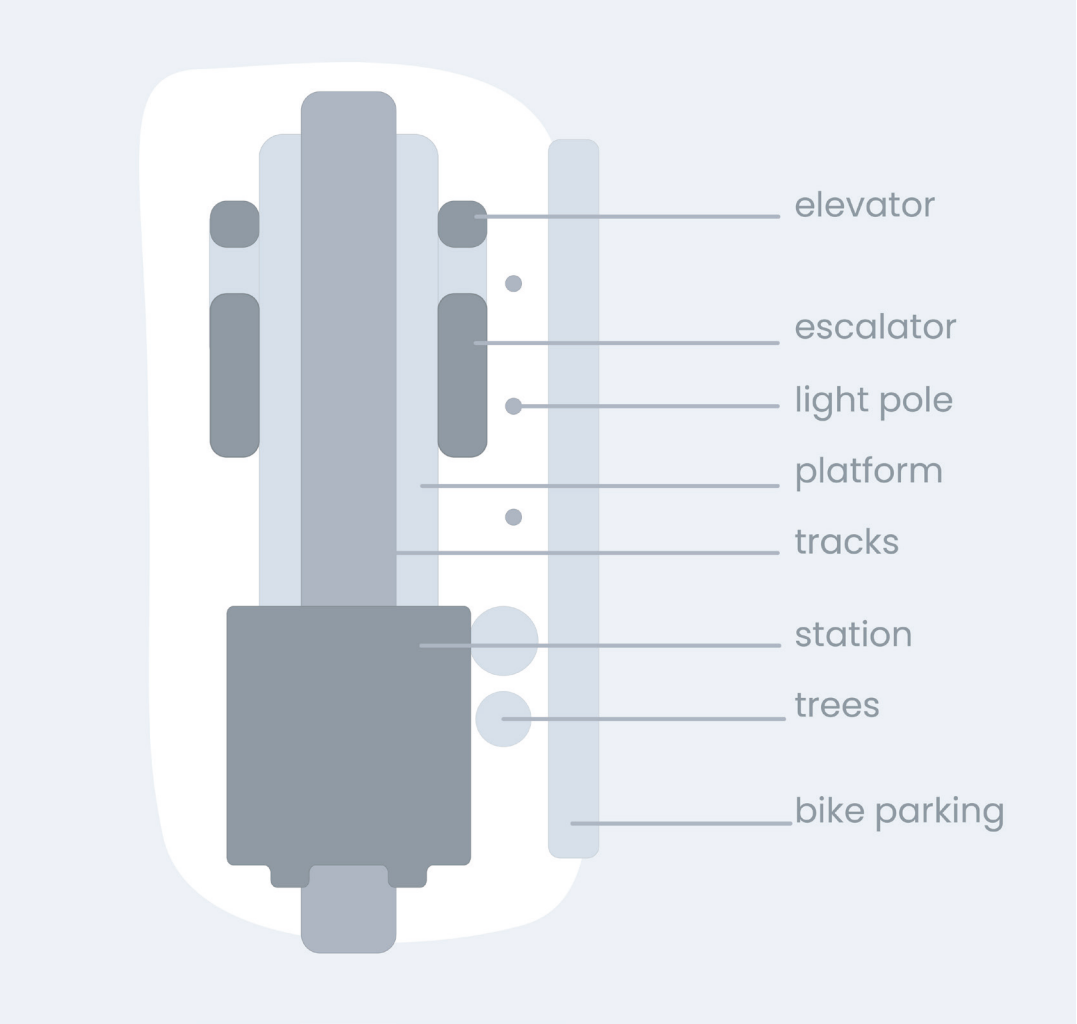


figure 6
project area

5.1.1 ILLUMINANCE MAP

For this analysis, a lux measure was deployed. Although each number in and of itself does not being much value, the holistic picture gained from this analysis aids the insights and understanding of the space. “Upon discussing the role of the lighting measurements, it was clear that while the lux value was in itself less relevant, it serves an important role as a fragment of the larger situation and setting. Therefore, the position and direction of the measurement would be as important as the measurement itself,” (Borgestrand Øien et al., 2024) Before starting this analysis I considered the intention behind the measurement as well as the position and the direction.

The levels were measured at a height of approximately 100cm distance from the ground, at a horizontal angle. For height of the measurements I considered the most common posture one would assume when walking through a station; Most people seemed to be looking slightly ahead but towards the ground, looking out for potential obstacles on the floor ahead such as stairs. Occasionally, doors would need to be opened as well. Door handles are placed at the same height making it a fit choice for measuring illuminance in this context.

The measures were taken on 15th of March at 3:30pm which included daylight and electrical lighting, and 7:30pm with electrical lighting only. The weather was overcast.

Figure 7 shows the illuminance measures.

Something that can be observed from the measures is that there is not a big difference between only electrical light and electrical light with daylight. In other words, even during the day the inside of the station is rather dark. This aligns with my perception of the station when doing the analysis as well. It indeed felt significantly darker inside and there was a stark change in contrast upon entering the building.

Another thing that stood out here was the luminaire placement. Both outside the station and inside majority of the luminaires are placed either next to walls or are wall mounted. Thus outlining the structure of the building rather than routes or objects. It can be concluded that the lighting here was not designed with the function of the building in mind, rather it was placed to compliment architectural features of the building itself.

figure 7
illuminance, daytime

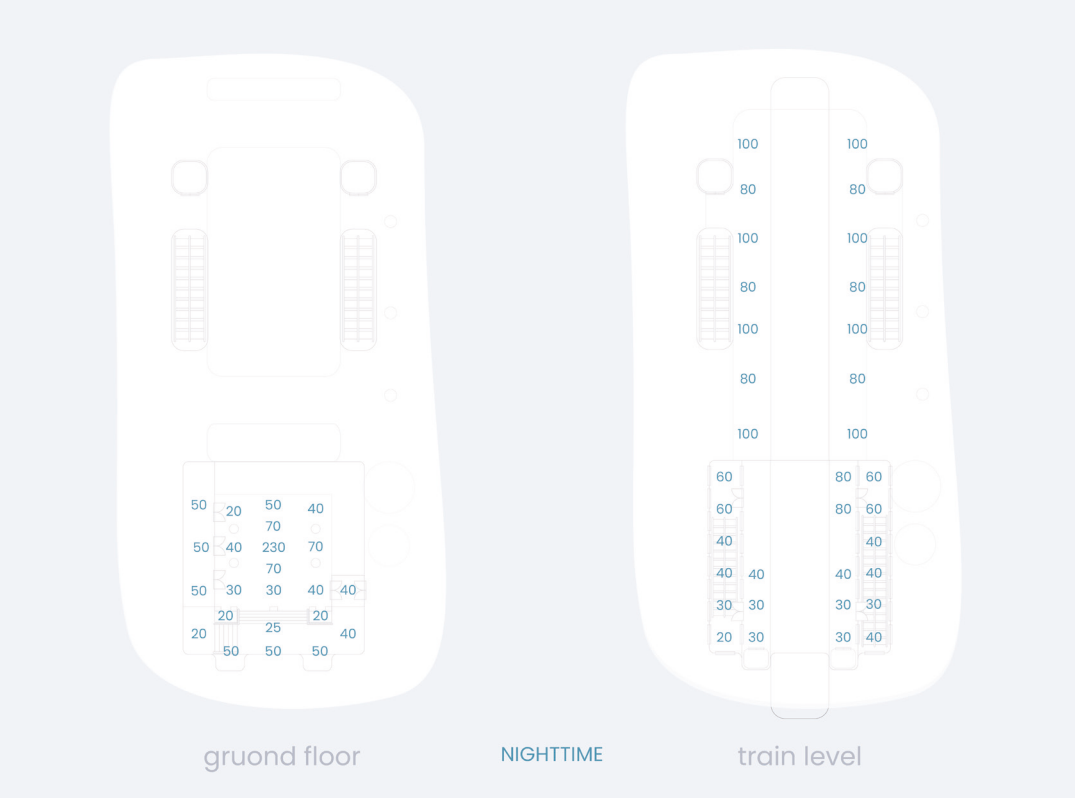


figure 7
illuminance, nighttime

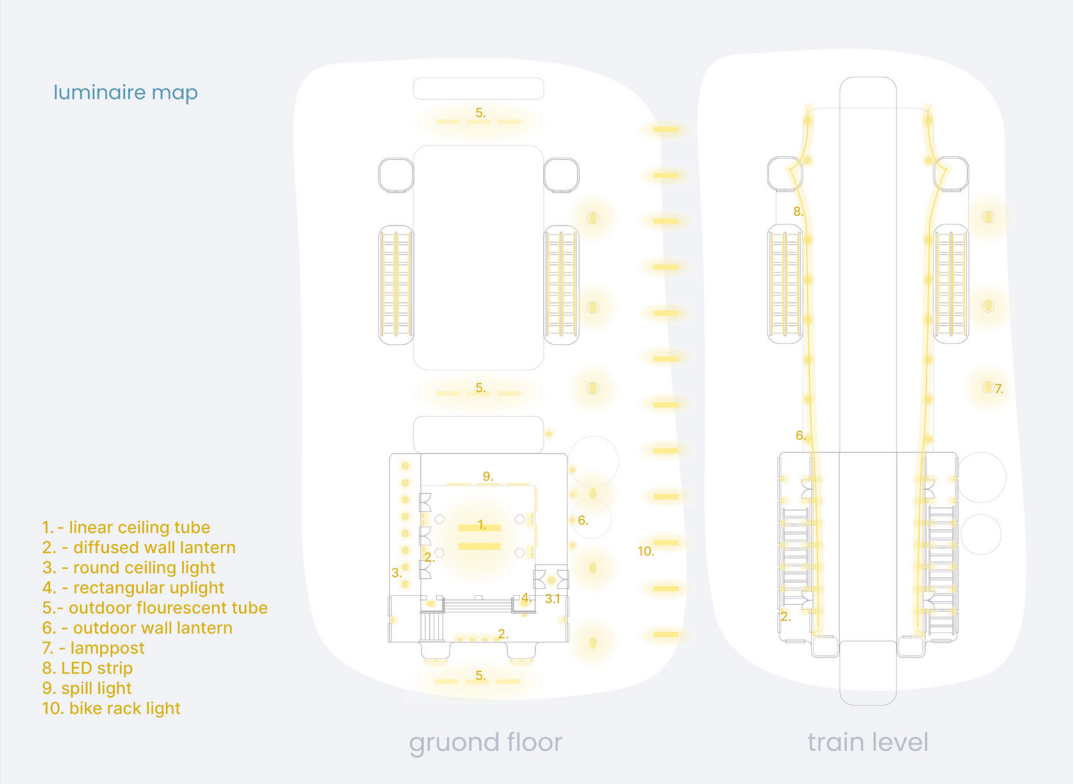


figure 8
luminaire map

figure 9

figure 10

figure 11

figure 12

5.1.2 LUMINAIRE ANALYSIS

Figure 8 shows the map of the luminaires and an illustration of the distribution of light in the space.

1 – linear ceiling tubes (figure 9)
Two of these, in neutral white colour temperature, are placed in the centre of the entrance hallway facing down. Although there are no exposed bulbs or LEDs they are very bright to look at directly. Most people would however not do that. They are not original fixtures from when the station was built and have seemingly been placed there to raise the lux levels. They are reminiscent of warehouse lighting to me.

2 – diffused wall lantern (figure 10)
In the station these the most commonly found luminaire. They are placed between all window and door openings as shown in figure 11. Although I could not find any publicly available information, these could be the original luminaires from when the station was built. This is my speculation only. Throughout the station they appear in various colour temperatures some of which even have a greenish hue. They are consistently placed, yet because of the difference in temperature, they are not perceived as such. Sometimes they are placed in pairs. The light they give off is low, soft, diffused and pleasant.

3 – round ceiling light (figure 12)
These can be found on one side of the station only as shown in the map. They give off warm diffused low levels of light. These are newer, likely from when the station underwent repairs. They remind me of luminaires one might choose for an indoor hallway, or a living room. Marked with a 3.1 on the map is a luminaire of similar properties, although a different luminaire. This seems to be of the same style as the diffused wall lanterns so it could also be dating back to when the station was built. My guess is that the luminaires marked with 3 used to be these as well but as they are outside and more prone to damage, they got changed to be what they are now.

figure 13

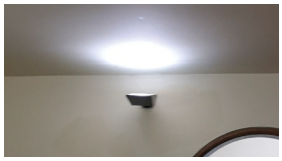


figure 14

figure 15

figure 16

figure 17

figure 18

figure 19

4 – rectangular uplights (figure 13)
These are placed in the openings of the main hall that do not lead to anywhere. Mounted to the wall they are pointing upwards to illuminate the ceiling. They are in cold white and were, like the first luminaires, likely put in to reach higher lux levels. As the ceiling is white it reflects the light into the space. They remind me of flood lights. I suspect them to have been put in alongside the first luminaire mentioned as they are both industrial looking lights.

5 – outdoor fluorescent tubes (figure 14)
Similar to their indoor counterparts, these come in neutral white. They are placed under underpasses illuminating down as seen in figure 111. There is three in each underpass. These have as well been added later on. They also look rather industrial and reminiscent of a construction site.

6 – outdoor wall lantern (figure 15)
Seems to be in the same style as the fixtures I suspect to be original. The ones on the tracks are standing on poles while the ones outside the station are attached to the wall. Shown in figures 111. They share the same qualities as their indoor counterparts, although these are more consistent in their colour temperature. They are all warm white.

7 – lamppost (figure 16)
These are incredibly tall and each have 2 luminaires attached to them. Their height reaches above platform level and thus they are visible from there as well. They give off warm light evenly illuminating the ground on the right side of the station. Figure 17.

8 – LED strip (figure 18)
A rather interesting feature of this station is the incredibly long LED strip that is hung between the lantern lampposts on the train track level. This seems like the newest addition to the station in terms of lighting. It is however not a permanent solution. The light is neutral white and it serves as a good guidelight for where the wall is. The idea with this LED strip was fantastic, but the execution needs improvement.

9 – spill light (figure 19)
Inside the station there is a 7eleven. With windows framing it, the bright shop lights spill into the entrance hall. The inside of the store is brighter than the rest of the station with lights being in a more neutral temperature.

10 – bike rack lights
These are LED tubes illuminating the bike rack on the right side of the station. A bit of their light spills onto the path to create an interesting patter when seen from afar. (Visible on figue 17) They are in warm white.

5.1.3 MATERIAL ANALYSIS

Having been built in 1930, this station has an interesting material quality to it. Materials influence the way we perceive a space and the way the light illuminates it.

FLOOR
There are two types of flooring in the indoor level. Shown on figures 21 and 22. One is a smooth surfaced tile while the other is a smaller textured brick. The tile gives of some glare from all the lighting. The surface on the ground outside is a matt slightly textured outdoor tile. (figure 19). Tactile paving, or a guide path is also present as outlined in figure 20.

"A guide path is based on two parts: (1) a guide strip and (2) a background." (Laurìa et al., 2018) It is meant for wayfinding for cane users. There are two kinds of tactile paving present at Nørrebro; the dot shaped and the bar shaped. "Dot shaped or bar shaped and are called Tactile Walking Surface Indicators (TWSIs)" (Laurìa et al., 2018) These are standard across Denmark. The line shaped is designed to indicate direction whereas dot shaped is placed in front of obstacles or destinations to indicate a warning.

WALLS
The walls are painted a warm white on the inside and green on the outside. Everywhere inside except for the entrance hall there is small teal tile lining the bottom half of the walls. Figure 21. The tile gives a greenish hue to the entire station on the inside. Same tile is present in the upper level of the station, on the walls facing the tracks.

CEILING
Lower indoor level of the station is painted in the same colour as the walls. Upper level, right under the roof contains beams painted in wall colour and a wooden ceiling. (figure 23) Ceiling dome above the track is wooden with beams.

WINDOWS
Large windows are placed on walls of he station parallel to the tracks. They allow in a lot of light on the upper station level and stairs leading up to it.

ARCHES and COLUMNS (figure 24)
In the entrance hall there are arches painted black with a wood trim. The columns in the same hall are also painted black.

The unique materials found in this station are likely original from the time it was built and should not be changed. They contribute to the building's charming atmosphere. Heavy use of the colour green results in greenish light being reflected throughout the entire building. The materials feel warm and slightly worn, like a memory of a past time. The final design will be created around the materials to work alongside them.

figure 20

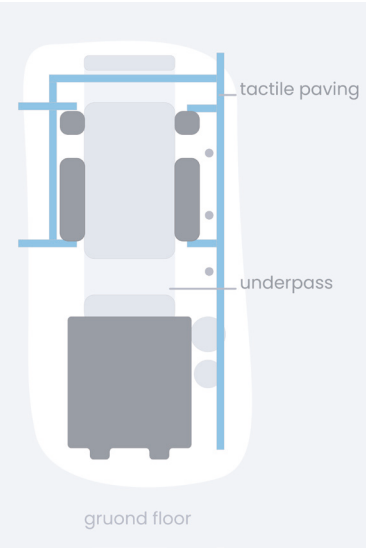
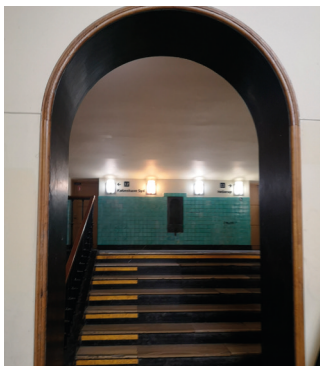


figure 21

figure 22

figure 23

figure 24



5.1.4 FINDINGS - NATURAL SCIENCE

The findings from the qualitative analysis can be summarized into the following bullet points:

- Lights are placed to compliment architecture rather than for the function of the space
- Low light levels inside the station result in an uncomfortable contrast
- The luminaire placement supports the lack of intention behind the lighting, with the exception of LED strip
- LED strip was a good idea but is not a permanent solution
- The station underwent a few changes in terms of lighting resulting in a messy overall outlook
- Materials are a unique aspect of the station, enriching its atmosphere
- Lighting in the station has shortcomings as in some cases it does not adequately indicate obstacles or aid the visitor throughout the space

Within natural sciences I focused on understanding the current context of the station, going forward this understanding and possibilities for improvement is the key takeaway I will bring into the final design.

5.2 SOCIAL SCIENCE

As stated in chapter 2 I find that research relating to BVI often focuses too heavily on quantitative data. Standards outline lux values instead of qualities of light.The fear of impossible solutions, assumed to be quantitively different, is one if the culprits hindering research on BVI related to outdoor and urban lighting. This chapter will detail the use of qualitative methodologies based on social science driven by the goal of understanding perception. All interview participants were informed of the context of the project and agreed to participate and be included in the thesis.

5.2.1 INTERVIEW WITH AN OCCUPATIONAL THERAPIST

METHOD

I had the opportunity to have an interview with an occupational therapist from IBOS. The interview was structured with questions written out in advance. The interview took place on the 5th of May. It was recorded and transcribed. Full interview can be found in appendix page 1.

Mette, the person I interviewed , works as an occupational therapist at IBOS. She works with visually impaired and advises on how to improve the struggles they're facing in their daily lives, primarily in the environment of their own home.

INTERVIEW

Throughout the interview my goal was to find out more about some common obstacles BVI might be facing, both in their lives at home and outside. Knowing about the preferences in their own environments gives insights into how outdoor lighting can be designed as well. And surely, there were some topic I had encountered in the literature, such as contrast, that were brought up in the interview here as well.

Contrast was mentioned both in terms of light and in terms of colour. She points out that outdoor paving tends to be just grey on top of grey. And for VI persons, this lack of contrast can be especially challenging in curbs or stairs if they are not marked.

I asked questions both relating to lighting and other obstacles. One interesting insight came from the conversation about floor materials. Mette recalled that a common advice given to people is the placement of carpets. For not only one purpose; it helps with glare issues if the floor is overly reflective, but it can also be used as an indicator of an obstacle. For instance, placing a rug under the table, one with larger dimensions, can alert the person of being next to the table when they walk on it.

She mentions how in their homes another common advice is to use light as a tool for navigating. Placing a light in the corner of the room gives them a frame of reference for how big the space is and similar. Furthermore, she confirms that uniform lighting is generally not very useful. It might illuminate everything, but that is not always helpful. As mentioned, more often than not having pools of light illuminating specific zones is better.

INSIGHTS

A lot of what was mentioned in the interview reaffirmed the findings from literature. What was also incredibly insightful is to hear more about how VI people use the space around them to orient themselves. The carpet insight being one of such things.

Overall, it is good to reiterate time and time again that although lighting preferences can be very individual, there are common struggles, such as contrast, that can be addressed in outdoor solutions.

5.2.2 WALK ALONG INTERVIEW

METHODS

As seen in previously reviewed research papers, walk-along interviews are a method to better experience and understand the perspective of the participants. I will follow the structure outlined by Borgestrand Øien et al. in their publication Situating the light: Methodology for sensory and spatial fieldwork.

This interview took place on the 11th of April, 2025 at around 3pm. On the route from Aalborg University building in Copenhagen to and in Sydhavn station. Route shown in figure 25. The interview was of semi-structured nature with some questions prepared in advance but with enough room for more questions that may arise during. The person I interviewed,Anette, is legally blind, being able to see light, and uses a cane. The interview was not recorded on a playback, however, notes and observations were being taken throughout.

As suggested by the article, the focus was on obstacles and issues faced along the route; “The main question of the interview guide would be what issues the participant has experienced, first of all regarding their current vision and lighting condition in the specific setting and at the specific time of the interview.” (Borgestrand Øien et al., 2024) The issues discussed did not necessarily need to be light related. Often times there are problems that can be solved by light that do not directly concern it. The goal is open-ended, to understand and observe rather than to inspire for specific solutions. Insights were the main goal of this interview.

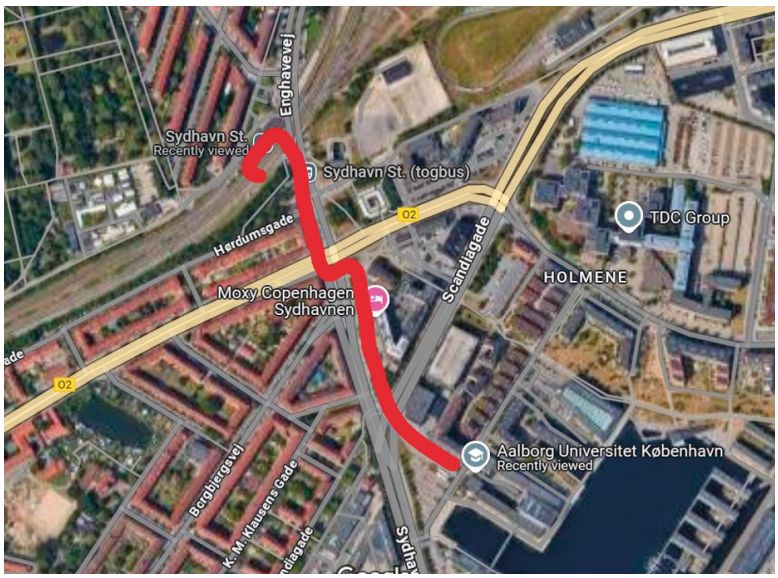


figure 25
route of the walk along interview

PROCESS

Aside from the general question regarding obstacles, I prepared these questions to aid the interview:

- How do different materials encountered along the route affect your commute?
- How much is your walking speed affected by an unfamiliar or challenging environment?
- How do you find the lighting in the station?

The street we walked along to reach the train station is one of the busiest in Copenhagen in terms of vehicle traffic. Along the way, when an obstacle arose, it would be pointed out and the conversation would focus in on that topic. Much how the article described it; “Zooming in and out on details, situations, and activities, as well as the thresholds and transitions” (Borgestrand Øien et al., 2024)

1. Obstacles on pedestrian paths

   On our way to the station, there was a vehicle with a trailer parked so that a portion of the trailer was on the pedestrian path. (figure 26) This appears to be a common occurrence, not only with cars but with bikes as well. Interestingly, Anette noticed it before her cane reached it. I asked how she knew but she did not have a definitive answer. In fact she said that she sensed it. This is how Kleege described her experience of the space around her as well. Sensing but on a passive level.

figure 26

2. Sound of traffic

   Crossing a street can be a challenge, depending on the surroundings. One of the crossings on the route does not have the acoustic signal box to indicate when the light has turned green. In this situation, Anette mentioned how she would either ask someone around her, or if there was no one, she would listen to the sound of traffic and the direction it was going in. If she could hear it on her left, going forward she would know that it is also green for pedestrians going the same direction.

3. Hand-rain shape

   Inside the station, an interesting observation brought up was regarding the shape of the hand rail; It is more useful when the handrails follow the shape of the stair. That way, when the stairs end or there is an interim platform, it does not come as a shock. (figure 27)

figure 27

4. Trains not stopping in the same place

   A common obstacle that comes with using public transport is that trains do not always stop on the exact same spot. With the exception of the Copenhagen metro. And therefore elevators, which tend to be placed in further ends of the station are unfavourable as they might leave further from a train than you would have expected. Stairs on the other hand are typically in the middle of the platform and are her preference.

figure 28

figure 29

figure 30

5. Doors

   Following the previous observation, doors of both trains and station buildings can be difficult to locate depending on their design. For instance, Anette points out how the door to Sydhavn station (figure 28) is poorly designed. Even though it has tactile paving markings to notify people of its presence, it opens out too far out, and the she even reported bumping into them once. One would not expect such doors in a station anyway. A more common type would be slide doors.

INSIGHTS

From these obstacles it is clear how much of what seems trivial to sighted people, such as shape of he hand-railing actually makes a difference. Another interesting observation to me was the second one regarding traffic. Using directionality of sound to orient oneself if an interesting insight into the perception of BVI.

As for the questions I mentioned, some valuable insights were gathered from those as well. Indeed materials greatly affect her perception of space. For instance, she prefers light ceilings as they reflect the light around the room better. This station had large posters with a dark frame placed on the walls (figure 29) she said how she uses the contrast of those for wayfinding and to identify the shape of the wall. In general, she mentioned how she tends to walk next to the wall and use it as a guiding tool.

She confirmed that her walking speed is severely impacted by an unfamiliar environment, and added that it is not only the walking speed. She states that a lot of energy goes into traveling and commuting. The walking speed is merely a byproduct and an indicator of this.

Finally, she commented on the lighting in the station as being too dark in the initial hallway you enter, and much nicer and brighter in the open hall area. (figure 30) She complained about the contrast upon entering the station as well.

5.2.3 OBSTACLE ANALYSIS

METHOD

Following the walk along interview at Sydhavn station, I went back to the location of my project, Nørrebro station to conduct an obstacle analysis. In my approach I refer back to Laurìa et al.'s paper on the use of luminance contrast in outdoor pavings. Whether or not something is an obstacle in the visual sense depends on whether or not it can be detected in time. "The detectability of an object depends on several factors: its size and form, the lighting, viewing angle and the visual acuity of the observer, the distance from which it is observed and especially the contrast with the background." (Laurìa et al., 2018) I will focus on four out of five of these factors as they are directly related to the object and not to the observer; size and form, lighting, distance observed, contrast with background.

As I have pointed out several times throughout this thesis, perception does not only rely on the visual. Therefore, I also anchor this method in the observations and qualitative insight gained from the previous interview in which I observed how other senses affect perception.

Overall, I am using two lenses, so to speak, to approach this analysis. First is an academic lens centred around the visual perception and second is a lens extracted from observation of a similar situation. With the goal being to identify potential obstacles that might hinder the commute of BVI.

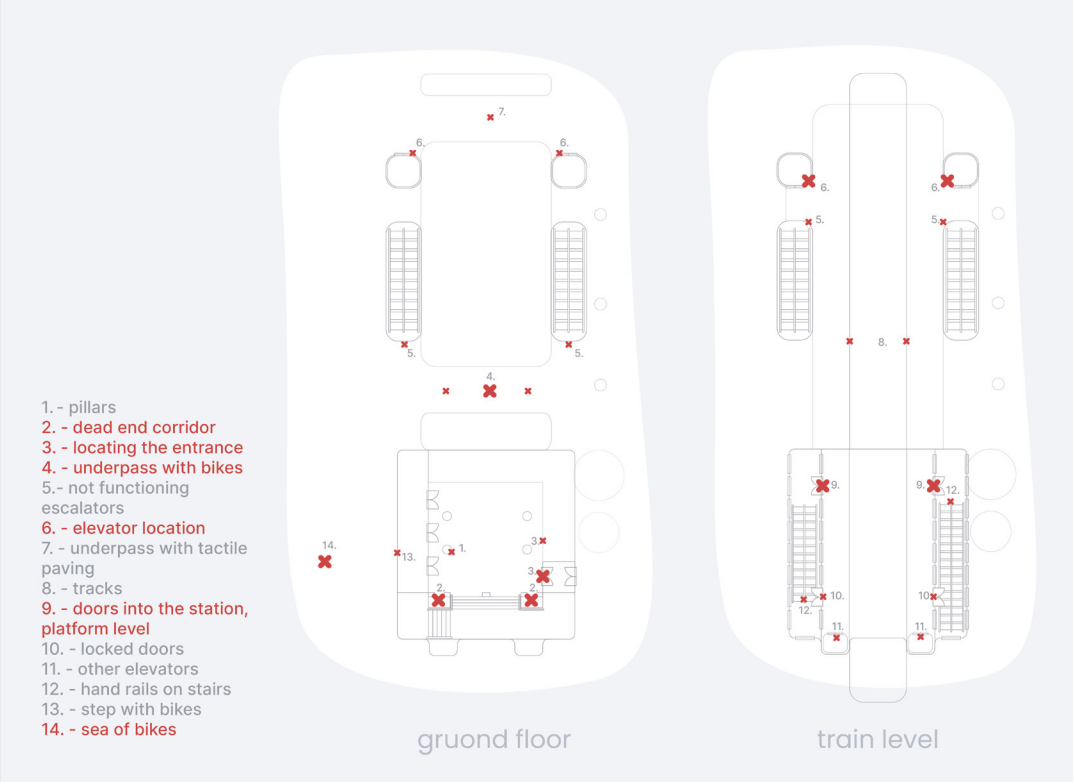


figure 31
obstacle map

figure 32

figure 33

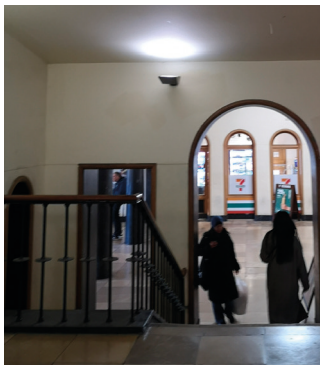
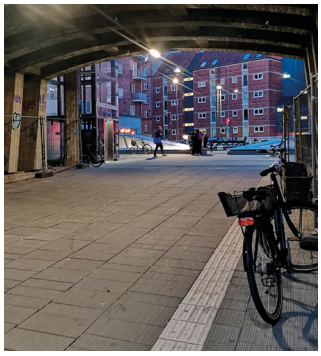


figure 34

figure 35

figure 36



PROCESS

I did not follow a predetermined route but instead walked around the entire station surveying its premises. I did not focus only on lighting related issues, rather I looked at architectural and wayfinding issues as well.

Figure 31 shows a map marked with all the potential observed obstacles.

1. pillars (figure 32)
As they are located close to exits, I think they could be a potential obstacle for someone looking to find a door. They are painted black which may pose contrast problems for some as this part of the station has low light levels. As mentioned previously, light on dark is a more favourable contrast in general.

2. Dead end corridors (figure 33)
These might be an obstacle for someone following the wall in their wayfinding as they are closer to the entrances than the stairs being sought out. Portion of the wall is painted black in an attempt to deter people from entering, however lights on the wall behind them might have the opposite effect.

3. locating the entrace (fiure 34)
The back entrance to the station is not bright enough to be noticed. The contrast between the 7eleven door which is right next to it is not sufficient either. In fact, the 7eleven door, which is an entrance only, one way door, is brighter.

4. underpass with bicycles (figure 35)
Underpass closest to the escalators leading to different platforms is filled with bicycles that often block the path. This is a definite obstacle for those who prefer not to take the elevator.

5. non-functioning escalators
When one does locate the escalators, they are, more often than not, malfunctioning. With no indication of whether they are working. Other than a lack of whirring sound coming from them.

6. elevator location
The entrance from street level is facing away from the station which might be unintuitive. Furthermore, at night, there is no specific light to indicate the location of the elevators.

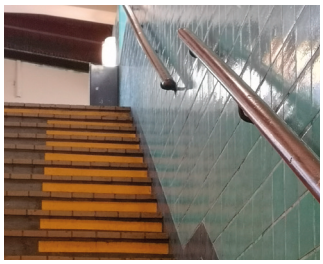
7. underpass with tactile paving (figure 36)
There are tactile pavings in the station. However, they take a seemingly confusing roundabout route and are sometimes missing. I have also seen bicycles placed on them.

8. tracks
Not enough contrast to see where the platform ends and drops into the tracks.

figure 37

9. doors into the station, platform level (figure 37)
Doors leading into the station are difficult to spot from the platform level. The window openings on the doors are aligned to the windows, which is beautiful architecturally, but potentially confusing visually. Because of all of the glass, the contrast needed to spot them is not sufficient. They are not distinguished by lighting either.

figure 38



10. locked doors
The exact same doors as the previous ones are located further into the platform. These are locked and do not lead to anywhere, yet they are equally lit up.

11. other elevators
There are two more elevators, one on each side of the platform. These are not marked in any way, nor are they lit up.

12. hand rails on stairs (figure 38)
The railing does not follow the shape of the stairs.

figure 39

13. a step with bikes (figure 39)
The station appears to be on a slope. Because of that a small step is placed right before the main entrance into the building. There is no contrast in the surface material of this step and it is not lit up in any way. Furthermore, there are bicycles often placed on top of it.

14. sea of bikes (figure 40)
Despite there being bike racks on the other side of the station, there is always a pile of bikes placed haphazardly in front of the escalators to the metro and left of the entrance to the station building.

figure 40

In the map (figure 31) I have marked those obstacles which I consider to be of higher importance. These will have priority in the final design, but all of these will be taken into account.

INSIGHTS

Quite a few of these obstacles are related to doors and entrances, which hold a significant value in architecture; “Perhaps one of the most professionally informed understandings of spatial perception among architects and designers is the importance and relevance of transitions and thresholds.” (Borgestrand Øien et al., 2024) I find it that the current lighting does not highlight this concept enough.

A number of these are concerned with safety. I believe they should be addressed in more way and not only with lighting. That being said, I will of course attempt to improve them with lighting.

5.2.4 WALK ALONG INTERVIEW WITH A MOBILITY INSTRUCTOR

After conducting my obstacle analysis at Nørrebro station I got the opportunity to do a walk along interview with one of the mobility instructors at IBOS (Institute for the Blind and Partially Sighted). A mobility instructor’s job is to introduce unfamiliar environments, such as stations, to BVI for them to be more comfortable using them and commuting.

METHOD

This interview was conducted similarly to the walk along interview in Sydhavn. I had outlining questions but left most of it to be determined on spot. The interview was not recorded, once again observations were noted down. The interview took place on the 6th of May at noon in and around Nørrebro station.

The mobility instructor, Stefan, had previously done an introduction to Nørrebro station as a part of his work. I had asked him to take me around the station and show how he would introduce it to a BVI individual.

The interview also consisted of general questions for an insight into situations and issues he encounters frequently.

PROCESS

We started on the platform, as if we had just gotten off of a train. From here Stefan would recommend finding a wall as this will be an easy way to find the stairs leading out of the station. He pointed out that generally, stairs and escalators are preferred to elevators, unless the person has a mobility issue. He also would recommend escalators in most cases.

He also addressed the issue of escalators in Nørrebro station which do not work more often than they do. A pointer he would give here is to touch the moving railing of the escalators. Both to identify if they are operating and which direction they go in.

After getting off the escalators he would recommend people to go around the station, along the road. Reason being the bike which are always blocking the path.

We then walked around the entire station to identify obstacles for other potential routes. He pointed out the tracks as well, the step in front on the main entrance and the big contrast in luminance when coming in from the outside. One obstacle

he highlighted specifically was obstacle 9 from my previous analysis – the doors on platform level.

As we stood beside the doors, a person with a cane got off the train and surely enough missed the doors we had just been talking about.

INSIGHTS

It was reaffirming to hear Stefan point out some of the same obstacles I observed in chapter 5.2.3. Furthermore, he shared valuable insight regarding BVI perception in general.

He said how a lot of VI persons do not like to use a cane and rather rely on their remaining vision, which aligns with the studies referenced earlier. It also shows a need for good lighting solutions.

Routes that are safer are a better choice than routes that are shorter. In the case of Nørrebro station although going straight ahead to the crossing would be the fastest when getting off of escalators, because it would take so much effort to avoid the bikes, a better option is to go around them altogether. This is aligned with what Anette said about how much energy she spends on just getting places. Same goes for level of complexity with routes; shorter routes with more turns are less favourable for the same reason.

When navigating space points of reference are important. Just how sighted individuals remember that in order to get home they take a right after the supermarket for instance, BVI individuals would do the same. But their points of reference might be based on other senses such as the sound changing when you walk under a bridge.

Looking up to see where the building stops and sky begins could be another point of reference. Because of contrast it might be difficult to identify how far ahead of you a street is. One way to go about this is to look up and observe the contrast between the sky and the building to know where the street in front of the building is.

An interesting insight was mention regarding the doors on platform level. Stefan has observed that BVI very accurately know when they are next to a wall. So it would be easy to tell when they've reached the covered area of the station, but the doors are unexpected where they are, also because they have the check in poles placed next to them which is uncommon.

In general, it feels much safer and grounded to walk next to a wall. Similarly, the same applies to standing around. This is again related to the point of reference. If you stand next to a bench, you know that you are next to a bench and that maybe there is a wall behind that and likely a trashcan nearby. If you don't stand next to anything, you automatically have less information about your environment.

5.2.5 FINDINGS - SOCIAL SCIENCE

Findings relating to the qualitative analysis conducted within this chapter can be summarized as follows:

- All senses work together to form an image on the space
- Objects in space are used as frames of reference in orientation
- Doors and thresholds hold significant influence over the experience of the space and should be approached with consideration
- Think of the energy being used for wayfinding
- Simplicity and safety is at the forefront of preferred routes
- Proximity of familiar objects gives reassurance in a hectic space

Within social sciences I focused on understanding the perception of the user, and going forward this perception is the key takeaway I will bring into the final design.

6. THE SENSES

Before I continue with the final section of the analysis, I will introduce the concept of senses and how I will be using it in the project. This will also be relevant for the analysis that will follow. Although I argue that all senses contribute to the perception of space, for this project and context I will be focusing primarily on touch and hearing.

6.1 THE SENSE OF TOUCH

For introducing touch into the methodology, I refer heavily to the work of Juhani Pallasmaa; His critique of the norms we've become complacent with in relation to the supremacy of vision. In his work he regards touch as the primordial sense people have lost over the evolution of technology and progressions in society. He advocates that the prevalence of isolation in current times is a direct result of other senses being neglected. "The significance of the tactile sense in human life has become increasingly evident." (Pallasmaa, 2005, p. 12)

This idolatry of vision, he argues, is not innate to us as human beings. "A primordial dominance of hearing has only gradually been replaced by that of vision. Anthropological literature describes numerous cultures in which our private senses of smell, taste and touch continue to have collective importance in behaviour and communication." (Pallasmaa, 2005, p. 23) He argues that throughout history we possessed a stronger relation with our other senses, such as hearing. Relating it back to the times where spoken word was the norm. He further gives examples of how our doctrines influence what we create. "We can even identify the transition of indigenous construction from the haptic realm into the control of vision as a loss of plasticity and intimacy" (Pallasmaa, 2005, p. 26) A culture which values the tactile above else, such as many indigenous cultures, will create architecture reflecting the same principles. Here he also brings in the concept of plasticity, a part of the haptic reals, as something we have traded in favour of vision.

He juxtaposes the eyes and the skin with the notion that eyes are the organ of distance whereas touch is that of nearness. Plasticity, as relating to the haptic, as relating to the skin and nearness has therefore been forgotten. He points out that we tend to close our eyes during overpowering emotional experiences; in an effort to feel more deeply we shut off the organ of distance. In architecture, the same effect is created by the use of shadow. (Pallasmaa, 2005, p. 43)

This regard of vision as the highest and noblest of senses was a gradual phenomenon, and has over time become apparent in our art and architecture. "The inhumanity of contemporary architecture and cities can be understood as the consequence of the neglect of the body and the senses, and an imbalance in our sensory system." (Pallasmaa, 2005,19)

Interestingly, he touches upon what I believe to be an egocentric view of space and architecture. Stating how it is the inherent understanding of our surroundings.

"Our bodies and movements are in the constant interaction with the environment; the world and the self inform and redefine each other constantly." (Pallasmaa, 2005, p. 39) He is right in saying that vision and technological advancement altered our perception. As the studies have shown sighted people to prefer the use of allocentric spatial representation. Pallasmaa, in accordance with his understanding of other senses, argues for the own human body to yet again become the centre of spatial perception. "Touch is the sensory mode which integrates our experiences of the world and of ourselves. Even visual perceptions are fused and integrated into the haptic continuum of the self; my body remembers who I am and how I am located in the world" (p. 13)

Although he does criticize the modern world and its progression, he points out how moving pictures for instance are a visual experience that encompasses other senses. "The haptic experience seems to be penetrating the ocular regime again through the tactile presence of modern visual imagery." (Pallasmaa, 2005, p. 34) He argues that since moving pictures can not be stopped and analysed, the sense of vision is not given enough time to overpower. Like a swimmer sensing the flow of water against their skin, we are left to sense the art through the motion.

Pallasmaa is concerned mostly with touch. Stating that all other senses are an extension of it. Accordingly, the ways to bring all senses, but specifically touch back into the space by the use of motion and shadow. In an effort to render vision as a secondary sense to finally allow other sensory inputs to take presence. With the use of shadow comes the rejection of uniformity. Shadow aids in perception of time. He further relates it back to the spoken word, and thus hearing, reiterating how the presence of intentional darkness strengthens other senses. Shadows being a beneficial tool is a belief aligned with the previously cited research on the preference of intentional contrast in everyday environments.

Based on his work, I would also add the egocentric spatial understanding, which he correlated to touch itself, to this list of ways one can go about bringing the senses back into a space.

6.2 THE SENSE OF HEARING

As for the sense of hearing, I will refer back to my own knowledge from working in Vega, a concert venue in Copenhagen. I already touched on the context briefly in the introduction. This will be a continuation of that.

My role was to be a lighting designer and a lighting operator. I got to sit in during the sound check and develop show concepts and implement them live. Over the course of my internship, I would humbly say that I have learned some things on the relation of lighting and sound. I was not merely probing in the dark on my own, hoping something would look good. I was mentored by industry professionals and had the opportunity to see the works of global guesting acts. Therefore, in relation to this project, I position myself as knowledgeable in the topic.

One of the most valuable realizations was the idea that light can be controlled. That it can be altered, moulded and shaped. What I describe is phenomenologically the very concept of plasticity in light. What allowed this plasticity was technological advancements in the field of light programming. But that is not the only thing that allows plasticity in light. That dimension is enabled throughout the use of other senses as well. When you are listening to a concert, you are not only listening or seeing, you are experiencing it with your whole being. You feel the vibrations of the bass. You hear the way the sounds echo in the room and see the way light follows a musical narrative. All senses come together to form the perception. Yet most of the room is dark, and the light is used intentionally. Not necessarily highlighting what one wants to see, such as the colour of the guitar or even the face of the artist. Vision is not in the forefront here. And the purpose of lighting is to convey ideas, thoughts and concepts. To illuminate fragments of the space instead of the entire reality. Because once the whole room is lit up, it is a sign that the experience has ended.

We can relate this back to even illuminance. Like Pallasmaa argued, shadows invite other senses, allow us to perceive emotion and time. A space devoid of shadow is a space of liminal reality; a space where there is no experience. A space where the experience has nor begun nor ended.

That was on the topic of plasticity in lighting. As for the auditory sense, I will retell how I approached the creation of concepts for the shows and things that I observed throughout my time there.

There are patterns in music. How we translate sound into light is by identifying these patterns. I would argue that this is done with intentionality and understanding of the context, through the use of tension, motion and layering.

Firstly, it is necessary to know the qualities of the music at hand, the aesthetic and feel it brings in. A punk concert sounds very different from a folk concert, therefore if we are aiming to accurately portray the experience, it should also look different. Understanding is half of the work. We can understand, recognize and predict the patterns in music to create meaningful visuals. Most modern music would have a build-up, followed by a stronger chorus which will drop back into a verse with build-up leading into another chorus, not to bore the listener there would be a switch up in tempo and an unheard melody which resolves in the biggest chorus yet.

Understanding this flow of music, the thresholds and tension points allows us to compliment it with lighting. The same can be done in architecture. By understanding the context of the space, we can identify the patterns within it and implement lighting to build an experiential narrative that follows the needs of those who use it. Just how lighting in music would follow the high and low points of the song; the build-up, the anticipation the excitement, light in public space should follow the trajectory of motion throughout it. Indicating the thresholds, the passages and the relevant surroundings.

Bringing in an auditory sense into a space throughout the medium of lighting means to forfeit the visual driven hierarchy in exchange for a holistic experience.

7. ANALYSIS PART 2

7.1 HUMANITIES

Earlier I posed a question of light having plasticity. Plasticity being “the capacity for being molded or altered” (Merriam-Webster, 2019). In physics light is considered as being both a wave and a particle. It passes through objects, refracts and dislodges electrons but has no mass. (Zeidan, 2023) Putting a filter in front of a light source would alter the luminous output. Making it a plastic, under the definition of plasticity.

The following section of the analysis will lay the groundwork for bringing this concept of plasticity into the final design. Before I can express lighting throughout other senses, it is necessary to understand how the space is currently perceived through these senses.

7.1.1 AUDITORY ANALYSIS

METHOD

For this analysis I spent approximately an hour walking around the station at different times of the day; around 11am, at rush hour between 4:30 and 5:30pm and at nighttime around 9pm, noting down the sounds I heard and my observations. Some of the sound was recorded and can be found in appendix-audio.

The analysis took place over the course of three days between 15th and 18th of April.

PROCESS

I observed some general patterns and some differences between the times of day. Firstly, rush hour is, as expected, the loudest. With more people passing, more noise, more footsteps, more commotion, more conversations and more traffic in the background. Midday was surprisingly peaceful and more often than not there was an occurrence of complete silence in the station, other than the mechanical noise of the train approaching. Nighttime was quiet as well, but in a different sense. The best way I can describe it is that it felt more hollow. There were no birds chirping in the background, and the city surrounding the station was quieter.

As I walked around the station it became evident how much architecture affects the sound. Not only does indoor sound different to outdoor. What I had not thought of prior, although it seems very trivial now, is that the shape of the room alters the sound. And so do the materials. Some spaces sounded like a tunnel. Taller more open spaces sounded taller as well.

An overview of the findings, grouped into different sound zones is represented in figure 41.

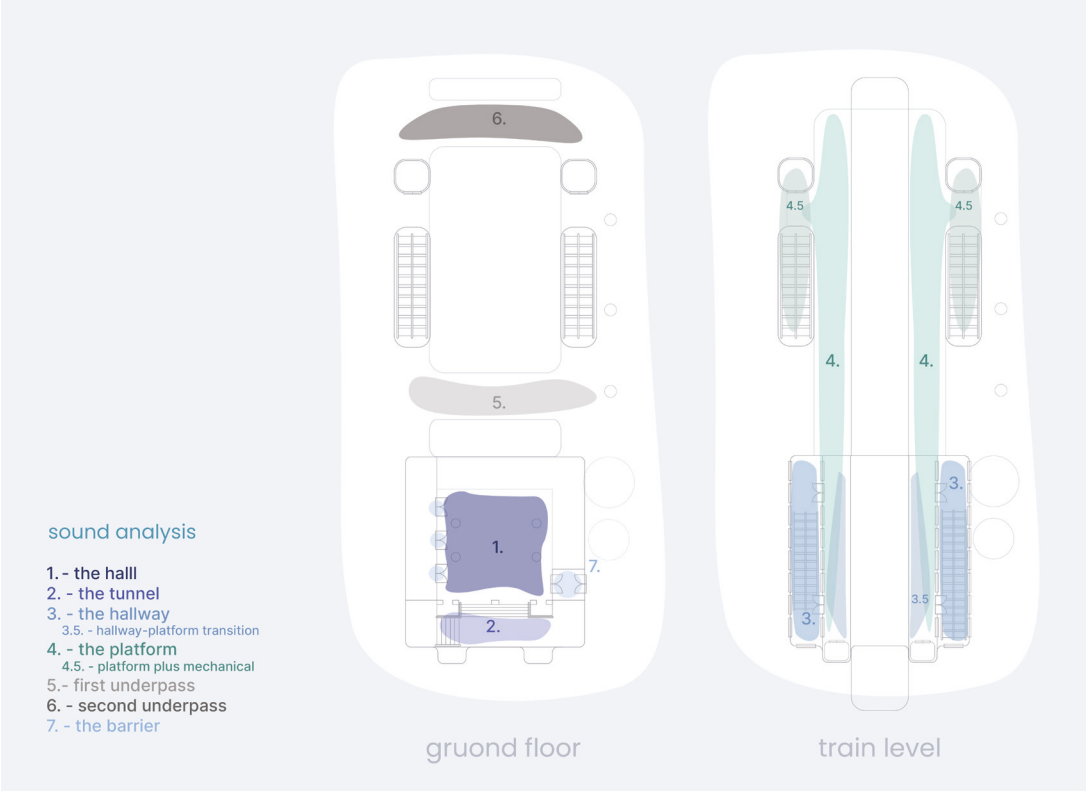


figure 41
Map of the auditory analysis

1- the hall
This area sounds large and open, but also somewhat underground. There is a certain kind of echo in it. As you stand there you can hear the sound of the train tracks directly above you as the train comes in. I was able to determine the direction with more focus, when the station was not as busy. You can also hear the people's footsteps as they descend from stairs and can determine which platform they are coming from. The sound here echoes around you and it feels as if you are in a giant barrel with an opening to one side only. The sounds feel distant in here.

2- the tunnel
Best was I can describe the sound here is to say that it feels closer to you. As if you can reach out with your hand and touch it. This room has lower ceilings and that reflects in the sound as well. It feels like you are in the middle of a tunnel. And you can simultaneously hear both ends of the tunnel. The sound of the tracks is audible here as well, but it is coming from the hallways rather than from above.

3 – the hallway
Compared to the hall and the tunnel, this area sounds quieter. There is no echo and it no longer feels as if you are underground. As you come up the stairs it gets even less echoey. The sound here feels warm and comforting. Some outdoor sounds are coming through as well as you climb up.

3.5 – hallway-platform transition
This covered section of the platform feels like a transition between the indoor and outdoor. The outside noises are much more clear now, but it sounds as if there is a barrier separating you from them.

4 – the platform
As this was spring time, the sounds I heard here were those of birds chirping, children playing in the distance and cars driving by. In other words, you can hear your surroundings here. When a train comes you can tell which direction the sound is coming from. The train does not sound overly loud. I would describe it as more pleasant and warm compared to the sound of the train in the hall.

4.5 – platform and mechanical
In the portion of the platform which contains the escalators and the elevator, the sounds described above get mixed in with the mechanical whirring of these.

5 – first underpass
This underpass sounds like the mixture of the hall and the platform. You can tell that you are outside, yet the sound echoes and the sound of the trains is coming from above.

6 - second underpass
On the day of my observation there was ongoing construction happening close by. Even though this underpass is under the tracks as well, it was near impossible to hear the train. It felt like the station was far away from me.

7 – the barrier
Lastly, I want to highlight the entrances to the station on ground level. These truly act like sound barriers. When you walk through them it feels as if you just burst out of a sound bubble. This is only the case with ground level doors. I believe this is because of the materiality of the station. On the platform level there is significantly more windows along the wall where the doors are. Sound travels with less resistance through glass than it does through a wall. Therefore the difference when you walk through this barrier is less drastic.

INSIGHTS

Sound is closely related to both the architecture of the space and to materiality. Often it overlaps, but occasionally there are significant differences in the spaces and passage between them. Evident from this analysis is yet again the importance of thresholds in space. I was also surprised to find out just how much information can be gathered about the environment from the sound alone.

7.1.2 TACTILE ANALYSIS

METHOD

For this analysis I referred to Kleege's account on meaningful sensations of touch – texture, temperature, and vibration. This analysis was done at once, around noon.

PROCESS

Once again, I found myself walking around the premises of the station. As our perception of touch is so focused on the hepatic, I feel the need to clarify that I did not walk around the station touching everything with my hands. Unfortunately, if someone had told me they had conducted a tactile analysis this is also the scene I would be picturing in my mind.

As I was walking around I paid attention to the material of the floor and how it felt to walk on. The different materials felt different to walk on. The tiles in the hall felt more slippery and the pavement on the platforms had the most traction. I did touch things, but only the things one would expect to touch, such as the handrail or the door. What was the most interesting to me was to feel the vibrations in the floor of the building when a train was approaching. The same vibrations were not felt standing on the platform. I believe due to materiality, and hollowness of the building.

Outside I could feel the sun and air on my skin. I also felt the changes in temperature as I walked up the stairs towards the platform. This area, the hallway as I had called it previously, is surrounded by windows that let in sunlight and therefore warmth in this time of the year.

The handrails were made out of wood and warm to touch. As it was warm outside most of the doors were open. The very few closed ones I did open myself. Doors are the same throughout the stations, they have wooden frames and thin metal handrails. The metal handrails were slightly cold but not unpleasant.

INSIGHTS

The most valuable insights here came from non-haptic tactile experiences. The vibration and changes in temperature is what I would like to highlight here. I have to admit that sometimes it really was difficult to discern which sense I was sensing with. I would be walking through the hall and as I heard my footsteps echo I almost wrote it down into the touch analysis of the space. But truly it is all interconnected. The sound of the tracks and the vibration you can feel at the same time are amongst the most interesting for me. I had never paid attention to that before. Even though if I were to experience it, my immediate though would be to picture a train coming.

As for the temperature and wind changes, I could discern if I was standing next to a window, if I was in shadow or if I was in the open air. Which, once again, sounds trivial but is something we do not think about because we can see where we are.

This analysis not only provided valuable insight into the space that is Nørrebro station and its experience. But it also taught me to appreciate my other senses more.

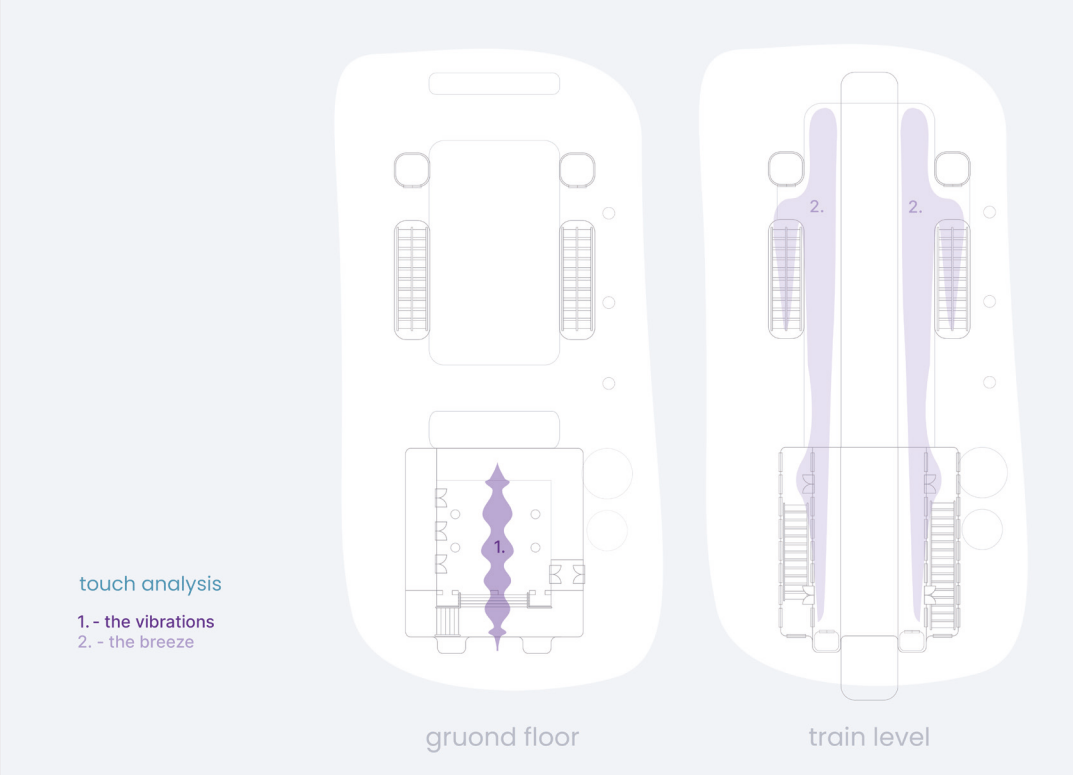


figure 42
Map of the tactile analysis

7.1.3 MOVEMENT MAP

METHOD

I had previously mentioned movement and the importance of understanding the use of the space. A part of that comes with understanding which routes people take. “the architectural approach is concerned with a holistic whole rather than individual parts, as well as trajectories rather than snapshots,” (Borgestrand Øien et al., 2024)

The data was gathered over the course of two weekdays, with observations taking place at different times of the day; 11am, 5pm and 9pm.

PROCESS

I observed across the station to see which routes were preferred by commuters at this station. The number of commuters were not counted as that would have been beyond my scope, but I did mark down which routes had more foot traffic overall.

A map visualising the findings is attached as figure 43.

Firstly, the least travelled route was the furthest underpass, the one with tactile paving. I only saw a handful of people pass here. Another unpopular route was the elevators inside the station. Likely because these are not noticeable. Following that were the outdoor elevators. Most of the people taking these were either with strollers, bicycles or had trouble walking.

The preference between taking escalators or indoor stairs seemed to depend on the proximity to them when, getting off of the train. An to the direction from which they were coming from for going onto the platform. For example those coming from the metro taking the train naturally took the escalators whereas those coming from the bus would choose the stairs.

When waiting for the train, rarely anyone stood on the platform much further than the outdoor elevators. Some people waited inside, on the second floor of the station. But most were gathered outside either around benched or the check in machines.

As expected, the station was the busiest at rush hour.

INSIGHTS

What surprised me to see is that there was not a clear preference between taking the indoor stairs or the escalators. This is likely influenced by the fact that the escalators at this particular station are often broken.

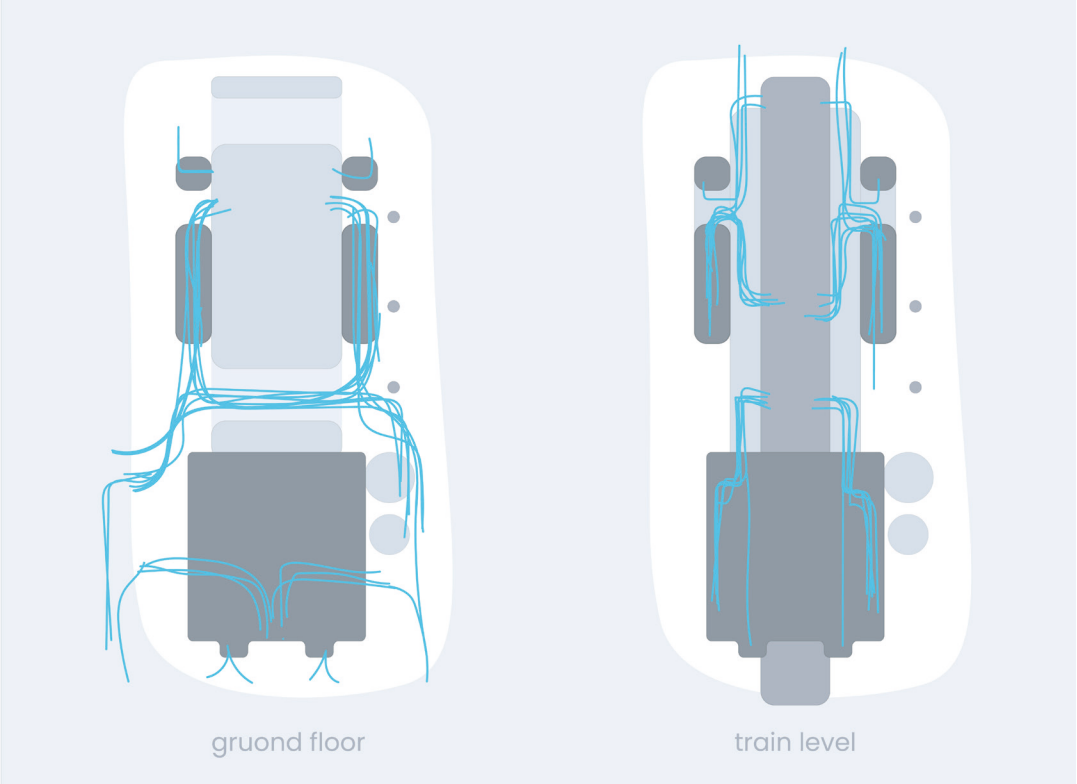


figure 43
Movement map

7.1.4 FINDINGS – HUMANITIES

Findings relating to the humanities and architecture can be summarized as follows:

- Senses work together to form a picture of the environment
- Sound, materiality and tactility and are intertwined already in our understanding of the space
- Rooms and spaces have their own distinct sounds
- Valuable tactility also comes from non-haptic experience
- Most people prefer shortest routes, which for them require the least amount of energy
- Passages and thresholds hold a significant value in our experience

Within this field I focused on the senses and perception of the space. In a way, these methods utilized a mixture of the findings from the other sciences. I revisited the station but used different analysis to reinforce some of the previous conclusions. And I approached the analysis by using insights from the social studies. As previously, the key findings will be reflected in the final design.

8. DESIGN OUTLINES

figure 44

figure 45

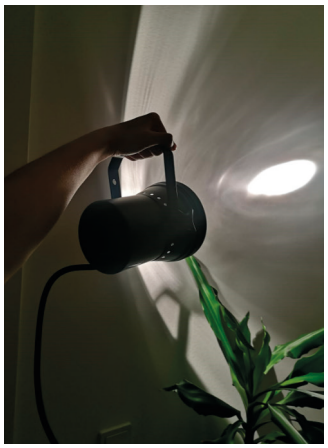


figure 46

8.1 SCENARIO TEST

8.1.1 METHOD

Similar to how in research papers I referenced earlier, a test involving testing of various luminaires would be conducted, I found it would be valuable to conduct a similar test as well. "The participants were subsequently invited to a lighting lab several weeks later. There, various lamps, light sources and arrangements were tested by the visually impaired participants. The participants were assisted by the low-vision consultant in comparing and assessing what worked best in specific situations. Following the tests, the consultant summed up the findings in a list of specifications for each investigated situation, and drew the optimal lamp arrangements on printed photos of each participants' home environment." (Borgestrand Øien, 2021) These tests would often feature multiple luminaires and the participants were asked to determine which one was the best fit for their needs. I will do something related, but with an adaptation for the context of my project.

The test, which I am calling the scenario test, took place on 8th of May at 4:30pm at Dansk Blindesamfund in Frederiksberg. It involved 7 participants with varying visual impairments. The test was conducted on premises that are not a perfectly sterile environment for mobility reasons. Daylight was blocked out as much as was possible and the existent electrical lighting was shut off. All of the participants consented with picture taking and the use of said pictures in the thesis.

The test was designed in two parts.

First part consisted of 3 scenarios. Each scenario corresponded with one of the auditory zones identified in the auditory analysis. Audio recorded from the same analysis was played on a speaker for the corresponding zone. For each of the scenarios participants were presented with a few different lighting options and asked follow up questions to understand their perception. The scenarios were not strictly structured, and all of the participants participated in the test simultaneously.

I had brought with me 3 different kinds of luminaires. I had 2 floodlights with adjustable directionality in neutral white (figure 44). 1 narrow spot beam in a warm colour temperature (figure 45), and 3 small linear LED lights in cold white (figure 46). I had also brought filters with me.

All of the luminaires were tested for each scenario, however not all of the combinations were possible to be tested out.

As there were many participants at the same time, the test was very open ended and flew more like a conversation. I asked questions throughout, some of which I had prepared. Others were a result of the conversation and feedback of course.

The second part of the test was a more general conversation with questions about the luminaires presented, about colours, preferences and similar. Although these two parts of the test blended together in reality.

8.1.2 PROCESS

The test always started with an audio recording of the space we were [virtually] in. I would ask a question where they imagine that we are based on the audio. The first response was a train station. This was followed by a question of which part of the station we are in. The first audio was from the entrance hall area. One of the participants said it sounded as if we are in a tunnel. Probably because of the echo. Once the location was identified I would turn on different luminaires.

What thrilled me as a lighting designer is that they had many opinions about them. Considering the room I was in, I placed the LED strips on the table at first. Facing towards the room. When I asked about how this lighting impacts the scenario immediately I got complaints about directionality saying it is too bright and too close to them. So I moved them further and tilted them slightly. I had also put them on the ground. This positioning was favoured by all.

As expected, some of the participants had differing opinions on lighting they preferred. One of the participants stated how she preferred darker environments with spots lighting up small zones of the room. After I brought out the spot light, she approved of it but said that she preferred an even dimmer and warmer spot. And one with a softer angle as well. You can imagine the excitement when I got such a detailed answer. Interestingly enough, later in the conversation, when I had asked them to recall an example of a station that has good lighting, the same person mentioned metro stations.

After the interview I did a quick analysis of the metro stations, and interestingly enough, light there is neutral white with no spots, rather with very diffused linear LEDs.

As mentioned, this was more of an open ended, conversation based test. As a result of that, often the first time a light would be presented would lead to discussion of its qualities. These conversations allowed for valuable insights to be collected as it allowed freedom to raise questions both for me and for the participants.

Figure 47 is a table comparing the group consensus on all the luminaires in different scenarios. Process pictures are shown in figures 48, 49 and 50 on page 46.

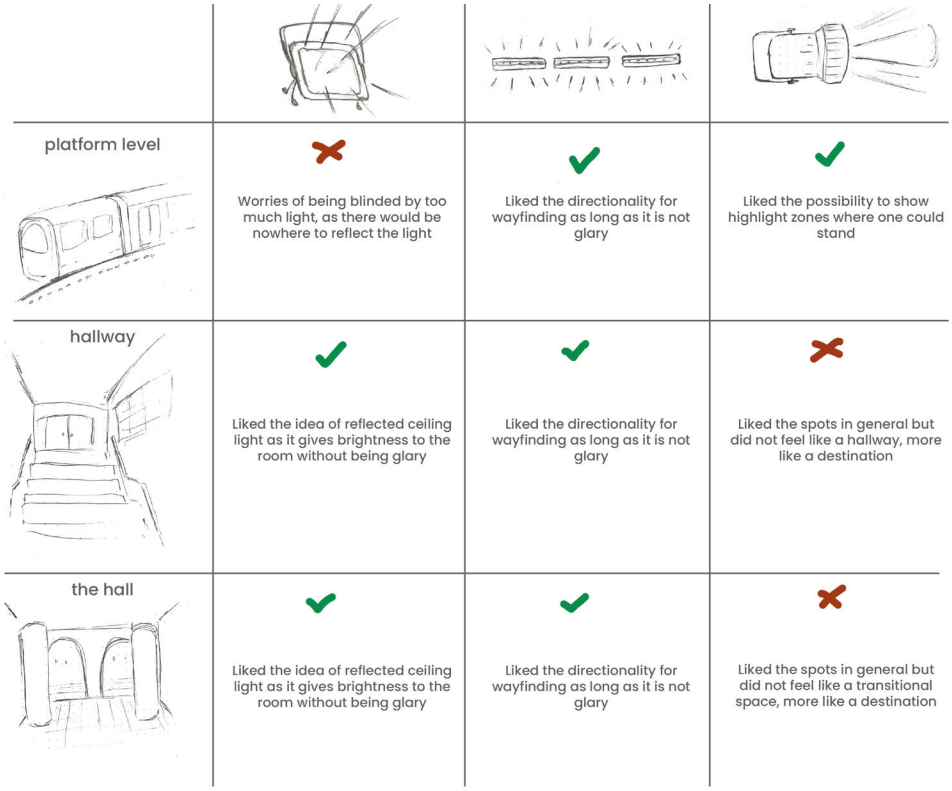


figure 47
chart of the reception of luminaires in scenarios

Hearing their opinions on coloured lighting was interesting as well. Purple was a polarizing option, with some liking how dark it was and some saying it is not nor them. Red got a funny reference to the Red Light District in Amsterdam. Yellow and green surprisingly were found to be pleasant for all. Overall they seemed to enjoy the filters, also because they dimmed the floodlights I had brought.

In terms of directionality, everyone yet again agreed that uplighting was the most enjoyable. The ceiling in the room was white giving the room a diffused illumination. Diffused lights in general were favoured as other types caused glare.

When I asked them about a station they do not like, I could not hear the end of complaints about Flintholm station. To which I say, me too. That station is probably the most confusing in Copenhagen. Another strong contender was Copenhagen Syd station. Both for having confusing layouts and being difficult to navigate.

I had also asked if they had been to Nørrebro station, to which the answer was yes. They pointed out that the other elevator, the indoor one, always has an unpleasant odour so they avoid it.

figures 48, 49 and 50
process pictures of
the scenario test

8.1.3 INSIGHTS

Although they knew a lot about lighting, occasionally they had contradicting opinions. Such as preferring spots and warm light but then naming the metro stations as an example of good lighting.

Placement was very important and often seemed to take precedence over brightness even. Sunlight can even be too strong. Their preferred weather is actually overcast. From that it is easy to conclude that diffused light is better.

Light is used for orientation. An interesting insight was brought up during the metro conversation. One of the participants said they really like the lights placed under escalators as it informs her of where the stairs are and aid in not bumping into them.

Once again, harsh changes in contrast, such as entering the station from the outside, were highlighted as pain points.

I had also asked about the preference stairs over elevator. The response was stairs over elevator. For the same reason as Anette, often elevators are placed too far.

One of the issues brought up was not being able to read the direction of the train on the boards.

8.2 DESIGN CRITERIA

Upon completing the analysis, some guidelines and frames of reference for the final design started to emerge. With the scenario test completed as well, a clearer outline for the final solution is beginning to take shape. Here I will condense everything into a checklist of most important issues and things to keep in mind. These are a combination of criteria laid out in chapter 333 and findings that emerged from the analyses and tests.

- Pay special attention to thresholds and transitions
- Bring in the experience of the space from the perspective of other senses
- Create clear wayfinding routes with lighting – think of the use of energy
- Pay attention to contrast and shadow
- Think in an egocentric spatial representation
- Utilize layers and tension
- Light directionality and placement
- Diffused light, be aware of glare
- Think of light as an aid in orientation
- Address the obstacles in the space

9. THE DESIGN

9.1 THE CONCEPT

There new lighting design revolves around 2 concepts.

The first one addresses issues and obstacles previously highlighted in the space and provides an inclusive lighting solution that aids in wayfinding of both visually impaired and sighted individuals. With the selection of luminaires, their placement and properties it comfortably guides the commuter throughout the space. The chosen fixture minimise glare by either placement or diffusion of light. In the solution the luminaires serve more purposes than simply being sources of light.

The second concept is an embodiment of what the space is perceived as by other senses. Rooms are illuminated in accordance with sound and touch. Lighting is not only there to illuminate the space but contributes to its overall experience. Different areas have different features and utilized light qualities in accordance with the senses. As the commuter moves through the space, the lighting follows on a conceptual level.

Figures 51 and 52 show the new proposed design from 2 angles.

figure 51
proposition for the platform

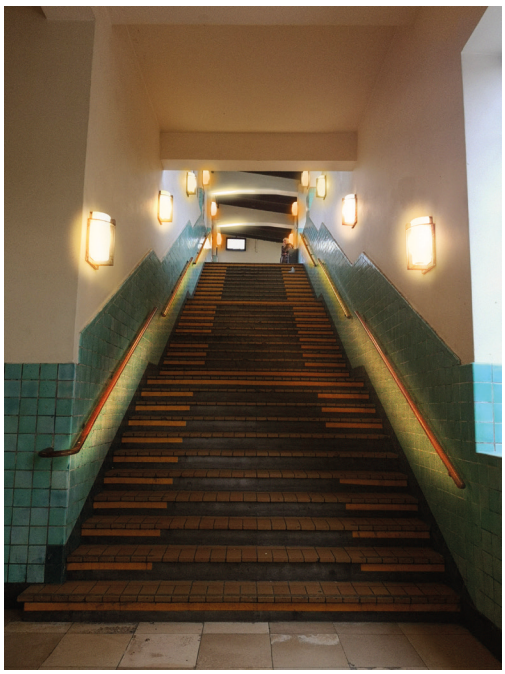


figure 52
proposition for the hallway

9.2 LUMINAIRES AND FUNCTIONS

The floorplan with the new design is shown in figure 53. Some of the old luminaires have been removed; previously marked on figrure 23 under the numbers 1, 3, 4, 5 and 8. Marked in yellow are the new added luminaires, while the ones marked in grey are the current ones that I propose to remain in the space.

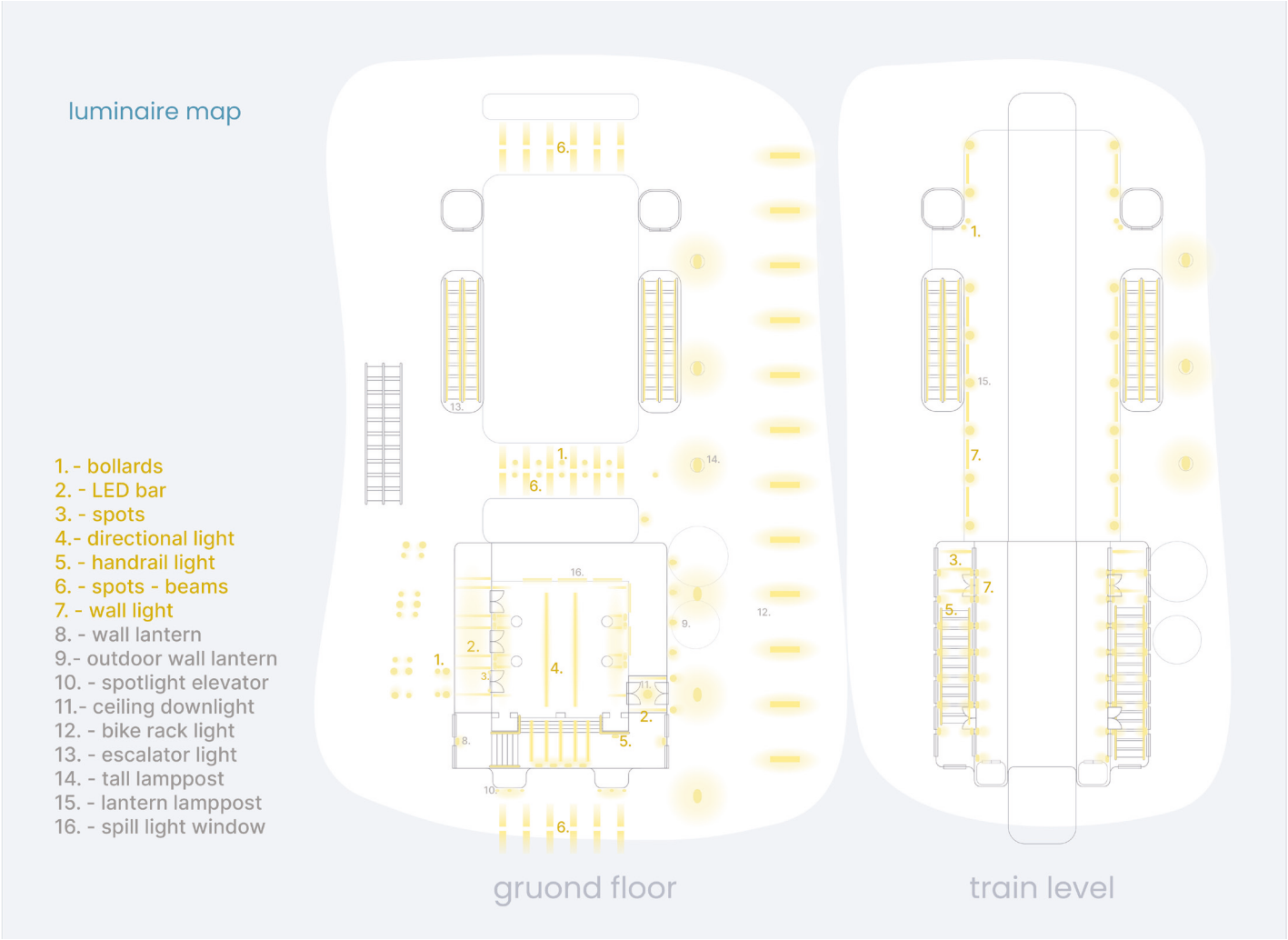


figure 53
new proposed luminaire map

figure 54
Flora bollard. Picture from the manufacturer website (Novantadieci, 2025)

figure 55
Slotlight luminaire Picture from the manufacturer website (Zumtobel, 2024)

figure 56
Spot light
Picture from the manufacturer website (Artemide, 2025)

1. **Bollards (figure 54)**

   Model: Flora 1126A by Novantadieci in standard and small size

   I use bollards as a tool to carve out a multifunctional path outside the main entrance leading to the metro and the escalators, and to mark the doors leading into the entrance hall of the station. One of the issues with the space directly outside the main entrance currently is that it is always flooded with bikes. By placing the bollards to form a path we can reclaim this space. The idea is that the bollards would be illuminating the space in the middle to create a clear path. I use two variations of bollards, a taller and a shorter one. This is done for two reasons, one is to control light levels and not to flood this area with the light. And second is that I believe the smaller bollards would act as obstacles as it would not be possible to rest bicycles on them, keeping the area free.

   The path is slightly curved. This way it can be used as an orientation device to lead one to both the metro if followed on the outside curve, and the train if followed in the middle of the path.

   I also placed bollards in front of one entrance only. This was done deliberately as there is an inconvenient slanted step in front of the other doors.

   Two bollards have been placed next to the outdoor elevators on station level for easier locating.

2. **LED bars (figure 55)**

   Model: Slotlight by Zumbtobel

   One of the main concerns regarding the thresholds of the space was the harsh change in contrast when entering from the bright outside. By placing these luminaires to reflect in the ceiling architecture, rather than to shine down, we can create a nicer transition between the indoor and the outdoor. During the daytime the luminaires here would work together with the daylight to create an illumination level in between the outdoors and indoors by seeming brighter than the lights inside. During the nighttime this would be reversed and they would be dimmer to allow transition into the nighttime.

   The same bars continue into the indoor area of the entrance hall, up to the columns and would operate under the same principle. By doing this we can extend the threshold zone to not be only in the doors but also in the area surrounding.

3. **Spots (figure 56)**

   Model: Calumet by Artemide

   Strategically placed spots illuminate the entrance which does not have a step in front of it. They are placed on the sides of the doors, illuminating the sides of the door frame pointing down to avoid glare. These also serve the purpose of marking thresholds. The same luminaires have been used in the indoor hallway area on the platform level. Here they have been placed to illuminate beams and signify transitions by directionality; they are placed closer to the doors, fading out into the other end of the room.

4. **Directional light (figure 55)**

   Model: Slotlight by Zumbtobel

   Ceiling lights would be placed as leading lines to signify direction of movement and to help wayfinding by going past the dead end corridors.

Light levels of this luminaire would be kept low as the purpose of it is not to illuminate but instead to show way. These also work in accordance with the senses by showing the directionality of vibrations and sound which can be perceived when a train is passing through. Additionally, I suggest the possibility to make them interactive; to signify by dimming when a train is about to arrive on the corresponding platform. For instance, if there was a train arriving on platform number 2, which is on the right of the station, the right beam light would dim and turn on in a short sequence.

The same lights would be placed in the tunnel area following the same principles. The tunnel area, as it is on a higher platform, is closer to the ceiling. By having lights at the same ceiling height we can signify the perception of the space through light. Furthermore, by placing the lights in this pattern we give the effect of being in a tunnel. I suggest these to have the interactive property as well.

figure 57
Handrail light
Picture from the manufacturer website (LEDHandrails, 2022)

5. **Handrail light (figure 57)**

   Model: Oak549 by LED Handrails

   I suggest the use of handrails with integrated luminaires facing down. The luminaires are diffused and the floor material in this are would not cause glare. They would utilize the concept of shadows and pools of light as they would illuminate the wall and edges of stairs but the centre. As seen from the analysis, walking next to a wall is preferred. This would improve that experience and make the handrail easier to locate and the shape of the stairs easier to distinguish. The handrail light would be differing in colour temperature. It would start out in slightly warm white at the bottom of the stairs and progressively get warmer. This would be in relation to the sensory experience of feeling sunlight through the windows.

figure 58
Spots
Picture from the manufacturer website (Erco, 2025)

6. **Spots on beams (figure 58)**

   Model: Kona by Erco

   Two spots would be positioned symmetrically, pointing out, on the beams of the underpass to signify directionality and the acoustics of the space. The same pattern has been used in the tunnel area indoors due to similarities in acoustics of these two spaces.

figure 59
Wall light
Picture from the manufacturer website (Novantadieci, 2024)

7. **Wall light (figure 59)**

   Model: Vela2443 by Novantadieci

   One of the bigger issues of the space were the doors on the station level that were difficult to locate. By placing a luminaire pointing up directly above the door we can draw attention to it from afar so people can spot it in advance and not have to look for it as they pass it.

   The same lights, pointing down have been placed alongside the wall of the platforms. These serve the same purpose that the current LED strip but are a more permanent solution. Furthermore, the strip as you have to walk under it to get to the escalators, serves as a point of tension and could even be confusing in terms of wayfinding as it is placed against or above a wall everywhere else on the platform.

   The new solution acts as an indicator of the wall as well, making it easier to locate. By default, as it is placed on a wall, the section that lacks it serves as an indicator of where the escalators are.

Integrating the existing luminaires

Wall lanterns can be used to give a soft illumination to the space. And as mentioned, I am not sure if these are protected or not, so I decided to work with them. The change I would suggest for them is to follow the change in colour temperature of the handrails in the hallway area. In the same way that the hand rail lighting does, I suggest them to get progressively warmer towards the doors to the platform.

The models mentioned are hight end luminaires and would be difficult to implement in a real life scenario. It is important to note that this project is a showcase of findings and an example of how to approach outdoor lighting for visually impaired rather than a concrete lighting proposal. Therefore, I would like to clarify that the listed fixtures are suggestions and have been chosen for representing the right qualities of light I wanted to portray.

9.3 REVISITING CRITERIA

In relation to natural science, I wanted to improve wayfinding not by focusing on the lux levels and standards, but by incorporating human based insight. I would argue that the wayfinding has been improved in several ways. Firstly, the bollards outside the station that direct foot traffic towards the trains and the metro. Secondly, with the use of directional light in the entrance hall and tunnel areas. Thirdly, by placing luminaires to indicate exits and entrances: both wall mounted and bollards. And lastly with the use of wall lighting on the platforms.

In relation to wayfinding I will also talk about the new routes created in the space. One significant change that I proposed is to leave the areas of the platform past the doors only illuminated by the wall lanterns. This will make the are darker, but this is also a route that was not in use and by utilizing shadow to virtually remove the route, we can reduce confusion and aid in wayfinding.

Another significant change in the routes is created by bollards. Which clear up the path of bikes and create a time and energy saving route.

In relation to social science I wanted to understand the perception of VI persons and how they might navigate the space to create a better design for them. In the luminaire list I already highlighted some of the obstacles and how they have been addressed. I would like to revisit my obstacle analysis and go through the most important obstacles.

1- Dead end corridor has been addressed with the use of directional ceiling lighting. (figure 60)

2- Entrances, both station and ground have been lit up by various luminaires for easier finding

3- Underpass with bicycles and the bicycles in front of the main entrance has been addressed with the use of bollards

4- Location of the elevator on platform level has been solved again by the use of bollards and by breaking up the sequence of wall luminaires (figure 51)

Furthermore, I used lighting to create points of reference and orientation by deliberately choosing to light up only one of the entrances for instance and by using varying luminaires throughout the space to help differentiate the surroundings.

figure 60
directional lighting

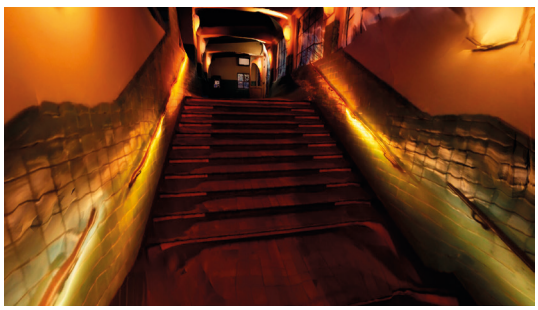
Finally, I would argue that the whole methodology of using the senses came about from understanding the perception of BVI. Which leads me to humanities. Within humanities I wanted to express the senses through light to improve the experience of the space. By reflecting what we perceive with other senses into lighting I created a homogenous experience. It is easiest to perceive an environment when it happens on a subconscious level. Or in other words, when you do not have to spend a lot of energy on deciphering what is around you. By indicating other perceptions through light I can aid in the amount of time and effort it takes to understand the space thus reducing stress and improving the experience.
But how have the senses been brought in? Through the use of plasticity. After conducting sensory analyses and outlining the characteristics of a space as seen by the senses, translating said characteristics into light, thus shaping it and giving it plasticity.
Through the use of shadow, contrast and egocentric space representation I brought in touch. Through the use of patterns, tension and contrast again I brought in sound.
Shadow is present in the hallway for example, in the centre of the room, because light is located at the handrail which is a direct haptic experience. In the hallway as well, the change in colour temperature correlates with the tactile experience of sunshine. The interactive element of the directional light brings in both the sensation of vibrations and echoed train sound.
Patterns can be observed in the way thresholds are treated. The same principle of illuminating the passage and illuminating the area surrounding it aids in the transition from the outside and vice versa. This has been done across the station, creating a pattern in concepts. Anticipation and tension has been brought in within thresholds as well, as the light helps to smoothen out the transition, thus creating anticipation rather than a shock.

9.4 INTELLIGENT LIGHTING FEATURES

I briefly mentioned the idea to use interactive lighting to show which of the platforms a train is arriving on.
I also suggest a use of coloured lighting to indicate weather or not machinery is in function. For example, having the lights lighting up the escalators turn red if they are not running. Or have the bollards next to the elevator do the same.
Often times the indicators for escalators not working, the same ones that inform about the escalator direction, are too small for VI to notice. Based on that, having a better indication would be beneficial.

More pictures and renders of the proposed design can be found in figures 61, 62, 63, 64, 65.

figure 61
View of the platform



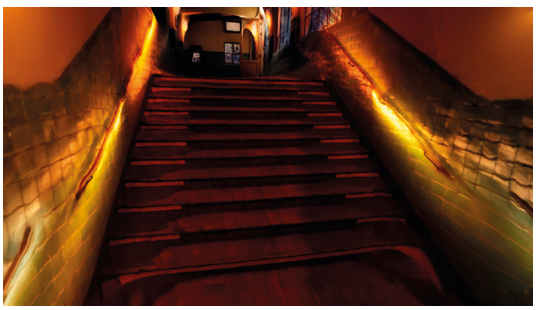


figure 62 and 63
Rendered view of the hallway with colour temperature gradually changing.

figure 64
Rendered view of the underpass with lit up beams. All the renders have been set to be at nighhtime. The lux levels, as they are rendered are not always the most accurate. But this still serves as a visualisation of the concept

figure 65
Rendered view of the threshold; one of the entrances on the ground floor

figure 66
Rendered view of the *tunnel with directional ceiling lighting*

10. FUTURE APPLICATIONS

If I were to develop this project further, I would apply the same process to other stations and locations in the city and extract from there a definitive methodology for rethinking urban public lighting. And of course, involve more participants and gather even more extensive data. Have scenario tests on site with bigger selection of luminaires and so on.
One thing that should be taken away from this project is the methodology and the approach. The human centred, and sense centred approach. It is an effort to create innovative solutions for everyone, and an effort to close the gap in research relating outdoor lighting and visual impairment.
In the end, this project is not a one-size fits all solution, nor was it ever meant to be. I am not suggesting that the exact same lighting fixtures with the exact same patterns should be implemented everywhere. This project is meant to serve as an example and be a showcase of a different approach in lighting design. Both in terms of visually impaired individuals, but also in terms of everyone's perception of space. The suggestions mentioned create value for the VI by addressing obstacles they face but they also draw from their experience to improve and add value to the space we all use. It is an example of inclusivity and enrichment challenging the way we think about lighting and the way we approach lighting related research.

11. ACKNOWLEDGEMENTS

Finally, I would like to formally express my gratitude towards all the people that contributed to the making of this thesis.
Namely, to Anette Bredmose, Susanne Tarp and the board from Dansk Blindesamfund in Frederiksberg, and to Mette Louise Murmann Frosberg and Stefan Pedersen from IBOS. Thank you.

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The end