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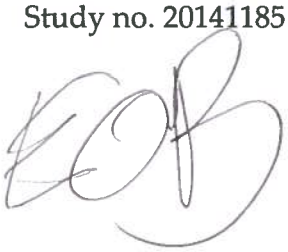

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Abstract:
The main focus for this master thesis project is the development of an overall lighting design concept for a specific path located in Roskilde, Denmark. The lighting design is created based on the question: *"How to create an innovative, sustainable and context adapted lighting design concept that through coherence, wayfinding and visual interest, invites people to use the Musicon-path?"*. The solution consists of four elements: A theme, layers, interactivity and timing. The theme is the concept of flow which helps to create a sense of coherence and adds variability along the path. The layers consist of a functional, spatial and effect layer. The functional provides the needed lighting on the path itself, the spatial layer enhances the feeling of safety and intimacy, while the effect layer adds wayfinding and a visual interest. The effect layer is interactive and dynamic at different degrees depending on the specific contexts at the specific squares. The dimming and on/off-cycle of the lighting is synched with the changing day/night-cycle throughout the course of a year, thus minimizing energy use and light pollution.

A second part of the master thesis project revolved about research investigating if it is possible to influence the walking speed of people using light through the question: *"Can a row of lights with animated intensities, along a path, affect people's walking speed?"*. The small scale test showed positive results that, at least, suggests that it is possible to influence the walking speed of people using a moving peak of intensity. This knowledge can be implemented in the specific design concept and is also potentially interesting for a row of other applications as well.

M.Sc. Lighting Design AAU CPH

THE MUSICON PATH

light that flows

AALBORG UNIVERSITY
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Submitted: 16-12-2016

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1 INTRODUCTION

1.1 PROJECT BACKGROUND

This report is developed as the final submission for the Lighting Design master programme at Aalborg University Copenhagen by Esben Oxholm. It summarizes activities performed and results created in the period of time spanning from September 2016 to and including December 2016.

The thesis is built around a project dealing with an overall lighting design of a future path between the train station in Roskilde and a new urban area, in the southern part of the city, by the name 'Musicon'. This path is henceforth referred to as the Musicon-path.

The Musicon-path project is part of the Lighting Metropolis project and the overall goal is to serve as a demonstration project for intelligent and sustainable lighting and in the future serve as a living lab.

The Musicon-path project is a collaboration between *Roskilde Municipality - By, Kultur og Miljø, DONG Energy - City Light* and the *Lighting Design master programme* at *Aalborg University Copenhagen*.

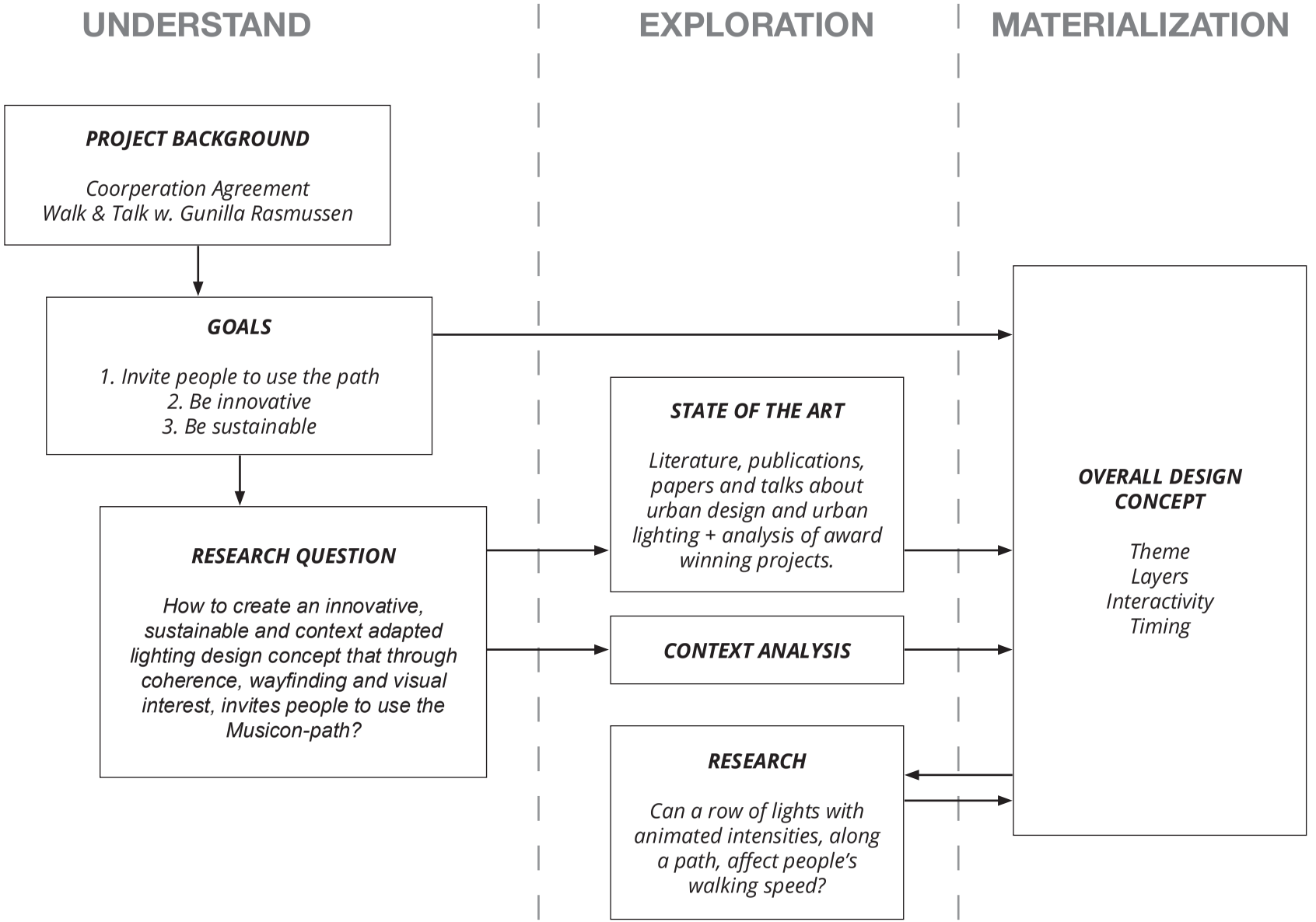
1.2 METHOD

Based on the nature of the project in question, the thesis is approached as a design based project. It has therefore been executed following the flow of understanding, exploration, and materialization. A graphical representation of the overall process is shown in ill. 01. It serves to provide an overall understanding of the entire process from the beginning to the final design concept.

This report is structured in a similar way. The following section describes the structure and provide a short paragraph explaining what to expect from each chapter.

2 PROJECT SCOPE

Chapter 2 provides a description of the overall goals of the project and defines the research question used as the project target.



Ill. 01 / Graphical representation of the project process.

3 CONTEXT
In chapter 3 the context of the Musicon-path is investigated and analyed. The findings are used as a basis for the development of the overall lighting design concept.

4 STATE OF THE ART
Chapter 4 describes the investigation of several different sources and projects with the goal of collecting a set of proven design principles that can be applied to the lighting design of the Musicon-path.

5 DESIGN
Chapter 5 describes the lighting design developed by weaving the knowledge and findings from chapter 2,3 and 4 together.

6 RESEARCH
To investigate the impact of a specific lighting design concept on the walking speed of people, a test has been conducted. Chapter 6 describes the specific research and the results.

7 CONCLUSION
Chapter 7 summarizes the entire project, reflects upon the findings and present future activities.

1.3 MOTIVATION

My personal motivation for taking on the challenges of this project is twofold. First of all, I believe that the cross-disciplinary approach to lighting design that I've been accustomed to through the Lighting Design master programme at AAU CPH is strong. The ability to understand the architectural and spatial features of a space and where its potential lies, is crucial for a successful lighting design. Coupling this with a knowledge of the physical attributes of light (and how it affects the space and the people it lights up), together with an awareness of today's and tomorrow's lighting technologies, makes for a package hard to match. From the initial description of this project, I believe that working within the fields of architecture, lighting technology and media technology and use them in combination, will be beneficial for the results.

Second of all, the actual theme of the project - innovative, intelligent lighting along a path - is one that I find interesting, relevant and important. As the population of cities gets denser still, I believe it is crucial, for the sake of the health of the individual, the environment and the liveliness of urban areas, that as many citizens as possible walk or bikes as a mean of transportation. This is true, not only for this specific project, but for most larger cities. The goal and challenges of this project is a typical example of goals and challenges that many new urban areas face. It is expected that the overall design developed for this project will contain elements and principles that can be used in other urban settings as well. Spending my master

thesis investigating and understanding how to invite people to use public spaces and develop a context specific lighting design that can support this, seems like a valuable use of time.

2 PROJECT SCOPE

2.1 GOALS

As mentioned in the introduction, the Musicon-path is part of the Lighting Metropolis Project with Roskilde Municipality as the main client and project owner. Therefore, before anything else, it is important to understand what their thoughts about, and expectations for, the project are.

The lighting design project was initiated with a couple of meetings in September 2016, with the purpose of defining the scope of the project and aligning expectations between the main project partners, Roskilde Municipality, DONG Energy and AAU CPH. The objectives agreed upon during the meetings are collected in a cooperation document. See Appendix 1 - Cooperation Document.

Besides the above mentioned document, information and thoughts about the project was gathered during a walk through the project area with project leader Gunilla Rasmussen from Roskilde Municipality. The talk was a casual conversation and was not documented, and served to provide a broader understanding of the context of the path and the goals defined in the cooperation document.

The takeaways, relevant to the development of a lighting design for the path, from the cooperation document and the walk with Gunilla Rasmussen can be assembled into three main goals and a row of sub-goals:

The lighting design on the Musicon-path needs to:

1. **Invite people to use the path**
    - *a. Guide people along the path*
    - *b. Invite people to stay and play at the squares*
    - *c. Give the path an identity on its own*
    - *d. Make the path feel short*
    - *e. Be interesting to a diverse user group*
    - *f. Adopt to several spatial and functional contexts*
2. **Be innovative through the use of existing technologies in new ways**
    - *a. Be able to notificate about events at Musicon*
    - *b. Work as a living lab*

3. Be sustainable

To help paint a clearer picture of the overall project scope, a few words has been written for each goal and sub-goal:

Invite people to use the path
The lighting design needs to invite people to use the path, as it is not the only way to travel between Roskilde Station and the Musicon Area. The lighting needs to have qualities that can change the minds of the people thinking of taking the bus or drive by car.

Guide people along the path
The path has several turns and not all are obvious the first times walking the route. The lighting design needs to clearly communicate these turns to make sure no users walks or bikes in the wrong direction.

Invite people to stay and play at the squares
Along the path, seven squares with different activities has been planned and will be build. The lighting design needs to support the different contexts of these activities and help make people interested to stop and use (or observe) the activities.

Give the path its own identity
By having a clear identity, it is assumed that the knowledge of the path is spread further. The lighting design along the entire path and at the seven squares needs to comply to a common theme to create an unified and coherent identity for the path.

Make the path feel short
The path is approximately 1 kilometer long, which for some people might be a stretch to walk. This is backed up by literature (Gehl, 2010; Naturstyrelsen, 2013) that describes 500 and 600 meters as a general threshold distance, that people are willing to walk. The lighting of the path should help to make the path feel shorter.

Be interesting to a diverse user group
The people expected to use the path is most likely going to have different rhythms, use patterns and individual goals. Making a lighting design that is meaningful for all users is important to make people want to use the path.

Adopt to several spatial and functional contexts
The path crosses busy roads, runs through residential areas and green areas. The lighting design concept, thus, needs to vary along the path to adapt to the respective contexts, while keeping a coherent perception of the entire path.

Be innovative through the use of existing technologies in new ways
As being a part of the Lighting Metropolis Project, there is a wish for the lighting to be innovative. However, to keep costs low, it is necessary to make the lighting design innovative by combining existing technologies in new ways. I.e. linking existing luminaires with an existing sensor technology to create a new type of interactive setup.

Be able to notificate about events at Musicon
The lighting design needs to have the ability to make people using the path aware of events happening in the Musicon area.

Work as a living lab
The lighting design should not be considered as done as soon it is implemented. It needs to be further adjustable and re-programmable to enable the possibilities of doing tests, to investigate how different settings affects the behavior of the people using the path, etc. This makes it possible to do further lighting design specific research in the future.

Be sustainable
For the sake of the environment and to keep the budget low, the lighting design needs to have a low energy consumption and be easy to maintain.

2.2 RESEARCH QUESTION

The main goal of this project is to develop an overall lighting design concept for the Musicon-path that meets the above described goals. Therefore, the research question that serves as the main driver for the project is defined as:

"How to create an innovative, sustainable and context adapted lighting design concept that through coherence, wayfinding and visual interest, invites people to use the Musicon-path?"

3 CONTEXT

Before doing any activities related to creating an actual design for the lighting of the path, it is important to understand the context on different levels. Therefore, in the following, the path will be discussed and described in relation to its larger context (macro scale), itself (micro scale), the users and environmental considerations.

3.1 MACRO SCALE

The Musicon-path is the second stage of a larger path project in the municipality of Roskilde. The large scale vision is to create a path running from Roskilde Fjord in the northern part of the city, through the city center, and through the Musicon area and Dyrskuepladsen to Viby, south of Roskilde. The Musicon-path is responsible for providing a safe and interesting connection for vulnerable road users (bikers, pedestrians, skaters, etc.), between the Musicon-area and the train station in Roskilde. See ill. 02.

MUSICON

Musicon is a new city district under construction, south of the center of Roskilde. It was established in the end of 2007 and is expected to continuously develop until 2030. Before the establishment of Musicon, the area has, since 1900, been used for agriculture, gravel pit, production of concrete and as a junkyard.

The main vision of Musicon is to mix cultural ventures, shops, residentials, and culture- and leisure activities, to create a living environment around the clock. Furthermore, Musicon is expected to work as a incubator for artists, designers, musicians and creative companies.

The development of Musicon is different than usual. Instead of a fixed masterplan, the district will be developed in collaboration with interested people related to the business, culture and residential development.

The keywords for Musicon are creativity, play and learning. In other words, the vision of Musicon is to create a dense area with lots of life during most hours. These keywords are further elaborated in ‘Musicon handleplan 16-19’ (Plan og Udvikling, 2015), where five overall goals are formulated, as :

A musical and creative district
Musicon must be based on the creating human with room for the the district's actors in cooperation to merge ideas and knowledge. [Musicon skal tage udgangspunkt i det skabende menneske med rum til, at bydelens aktører i samspil lader ideer og viden mødes.]

Life before city - and city with life
Musicon must have activity throughout most of the day. Different applications should be mixed and temporary activities should create variability, ideas and knowledge through experimentation. [Musicon skal have aktivitet det meste af døgnet. Forskellige anvendelser skal blandes og midlertidige aktiviteter skabe foranderlighed, ideer og viden gennem eksperimenter.]

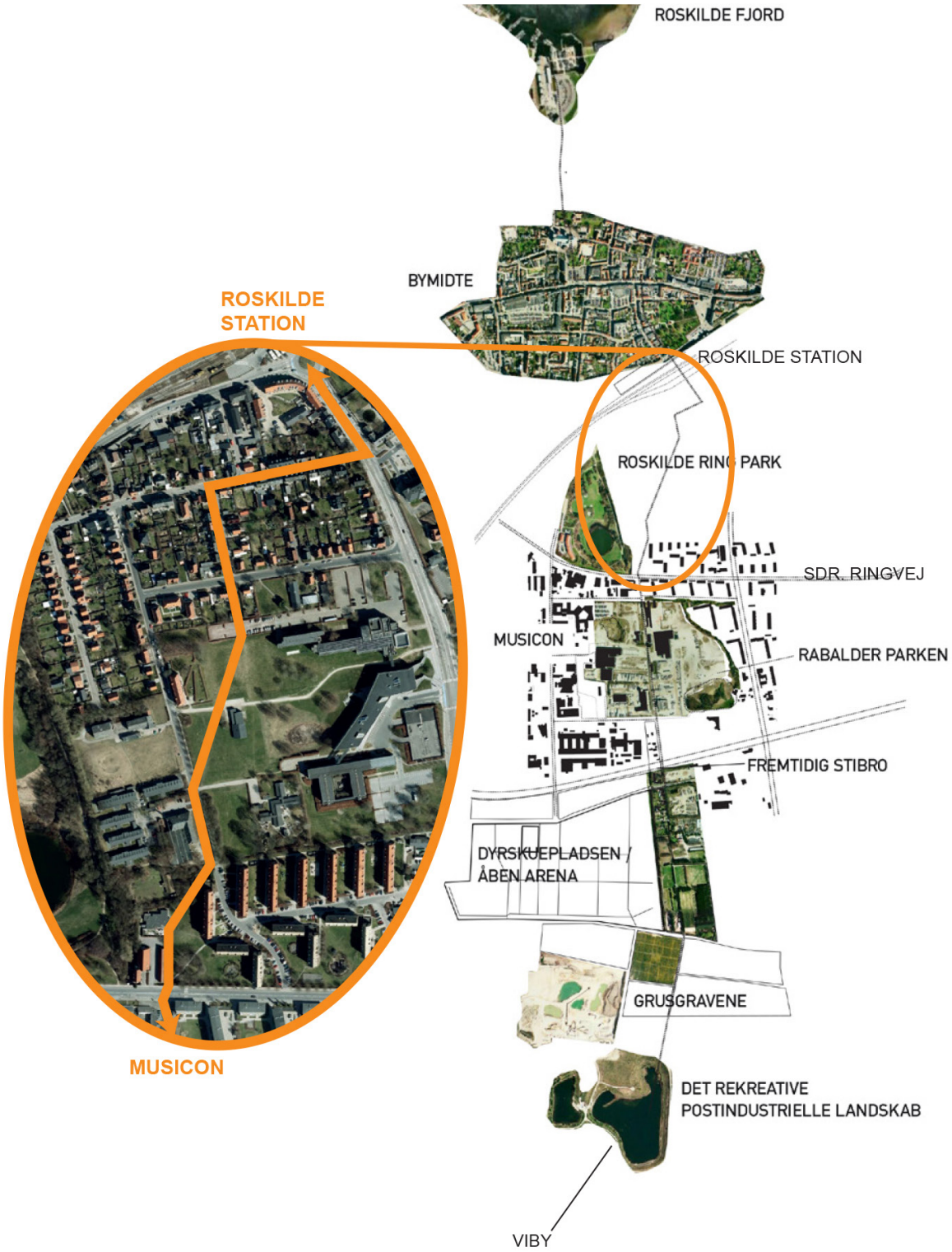
Experimental construction and industrial traces
Buildings and urban spaces in Musicon should be eventful and challenge the visitor. Musicon has a raw and industrial look, and projects will build on the tracks in the area. [Bygninger og byrum på Musicon skal være oplevelsesrige og udfordre den besøgende. Musicon har et råt og industrielt udtryk, og projekter skal bygge videre på spor i området.]

A laboratory for sustainable traffic
Musicon must be a laboratory for sustainable traffic. Musicon must offer the best conditions for walking, cycling and busses and car parking must be the least prominent in the urban environment. [Musicon skal være et laboratorium for fremme af bæredygtig trafik. Musicon skal tilbyde de bedste forhold for gang, cykel og bus, og bilparkering skal fylde mindst muligt i bymiljøet.]

An environmental friendly district
Musicon must focus on innovative and sustainable solutions. Impacts of undesirable substances and greenhouse gases must be limited through new and experimental knowledge. [Musicon skal have fokus på innovative, bæredygtige løsninger. Påvirkninger af uønskede stoffer og klimagasser skal begrænses ved at benytte ny og eksperimenterende viden.]

When the Musicon district is finished in 2030 it is expected to contain 650 residences, 5.500 m2 detail, minimum 2.000 creative workplaces, 33.000 m2 culture, 32.750 m2 education, 15.000 m2 hotel, 6.000 daily cyclist and 9.000 walking people between the train station and Musicon. Although 2030 might seem like far into the future, there are already a lot going on in the area. In 2015, 190 events was held, 200 residentials was build along with Ragnarock, a museum with the history of rock as a pivot point. (Plan og Udvikling, 2015)

An interesting feature of the design of the Musicon area, is the way the local drainage of rainwater is implemented. The approach has been to collect the rainwater in open channels in Rabalderstræde and lead it into a 110 meter long rainwater system in Rabalder Parken, that, when dry, doubles as a skate area for skateboarders, bmx, inliners, etc. In this way the water



Ill. 02 / Overview of the Musicon-path in relation to the entire planned connection from Roskilde Fjord to Viby.

is made an attraction instead of a problem and gives the area an identity.

ROSKILDE TRAIN STATION

The other end the path will connect to the train station in Roskilde. Right now it serves as a barricade splitting the city into two separate parts with nothing much to offer other than the typical elongated grey platforms and the mandatory 7-eleven. However, it is facing a major redesign in the following years, created by the architectural firm EFFEKT, that will make up for this. In the words of EFFEKT:

"One of the key elements of the design is the integration of the station into the surrounding city. This is achieved by transforming the railway station into a large urban space that will become a new destination in the city with vibrant city life, shops and public spaces right on platform." (EFFEKT, 2016).

See ill. 03 and 04.

SUMMARY

The above description of Musicon and the train station is by no means exhaustive. However, it outlines the overall vision of the area and gives important hints about the type of context the path and its lighting needs to adapt to. In general, keywords like creativity, life and sustainability are important for the area and should be reflected in the design of the lighting for the path.

3.2 MICRO SCALE

With an understanding of the outer framing of the path, let's have a closer look at the path itself and the context of which it runs through.

ROUTE

As mentioned earlier, the path is going to run between the train station of Roskilde and the Musicon area. Although it has not been build yet, the route and squares with different activities along the path has been decided. The route of the path and the location of the planned squares can be seen in ill. 05.

In words, the path runs from the train station along Køgevej, turns and run along Knudsvej, turns again and runs along Thyrasvej, crosses Gormsvej and through a small green area enters Rådhusparken. It merges with Eriksvej and goes through a green area until it crosses Søndre Ringvej and ends at Rabalderstræde in Musicon. The squares are located mainly at intersections. Square 1 at Køgevej/Knudsvej, square 2 at Knudsvej/Thyrasvej, square 3 at the green area leading up to Rådhusparken, square 4 at the wrestling-club in the center of the park, square 5 where the park transitions into a narrower area, square 6 in the middle of the green area just before Sdr. Ringvej and square 7 marks the intersection of the path and Søndre Ringvej.

Ill. 03 & 04 / EFFEKT's visualizations showing Roskilde train station as it is today and after it has been rebuild.

The squares divides the entire path into smaller segments. To give an overview of the squares and path segments, a summary of their features and individual contexts are presented in ill. 06. The flow of spatial qualities presented in the table are based on quantitative observations of the area, documented in Appendix 2 - Spatial Flow.

3.3 USERS

Another important factor to understand in relation to create a meaningful lighting design, is the users of the path. Who are going to use it, when and why?

Based on information about the Musicon-area, it is assumed that the reason for the use of the path can be divided into the following segments: Work, education, leisure and cultural.

Work
This is the group of people using the path to go to and from work. Both people working in the Musicon area and the residents in Musicon, going to and from the train station to get to work in another city.

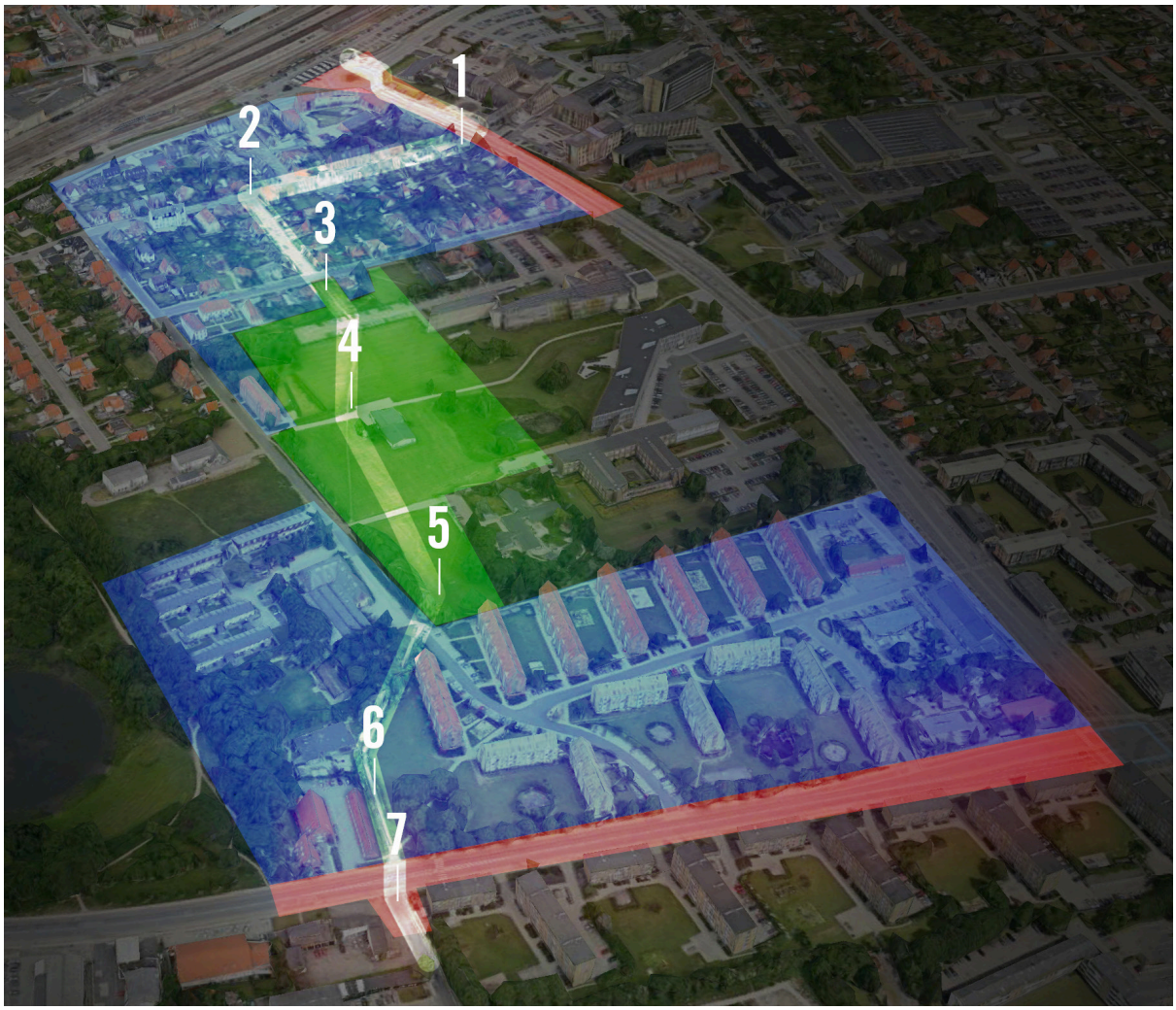
Education
This group contains, amongst others, the students from the Roskilde Tekniske Skole and HTX positioned in the southern part of Musicon. The children related to Børnehuset Reden is also contained in this category.

Leisure
Leisure activities are a big part of the Musicon area. This group covers the people coming to the area for skating, wrestling, climbing, dancing, acting and scouts to name a few.

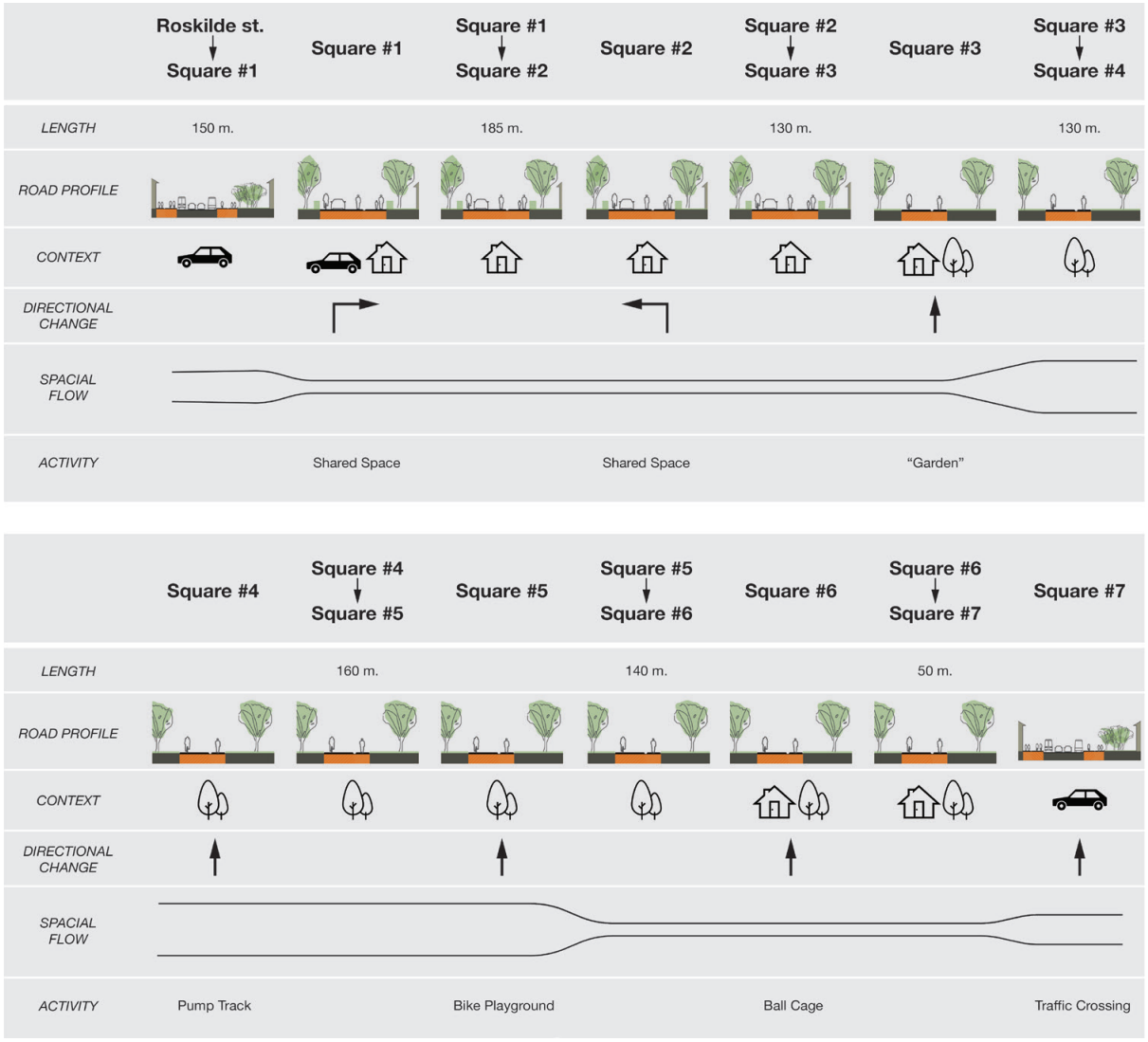
Cultural
This is the group of people coming to the area for i.e. exhibitions at RAGNAROCK, underground concerts at Paramount, and special events in the area in general.

To give an overview of these groups and when they are expected to use the path, ill. 07 has been created. The usage periods is based on the general work/school hours in denmark, opening hours for museums and venues and data registrations of bikers using the route already as shown in ill. 08.

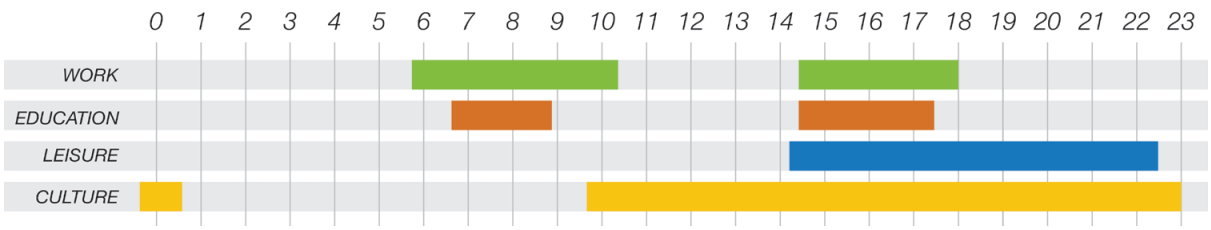
Although the user group is fairly diverse it is possible to group them into two overall categories: The daily/weekly users and the monthly/yearly users. The work-, education-, and leisure groups is expected to use the path either daily or several days a week while the culture-group is expected to come to the area between once a month to once a year (or less).



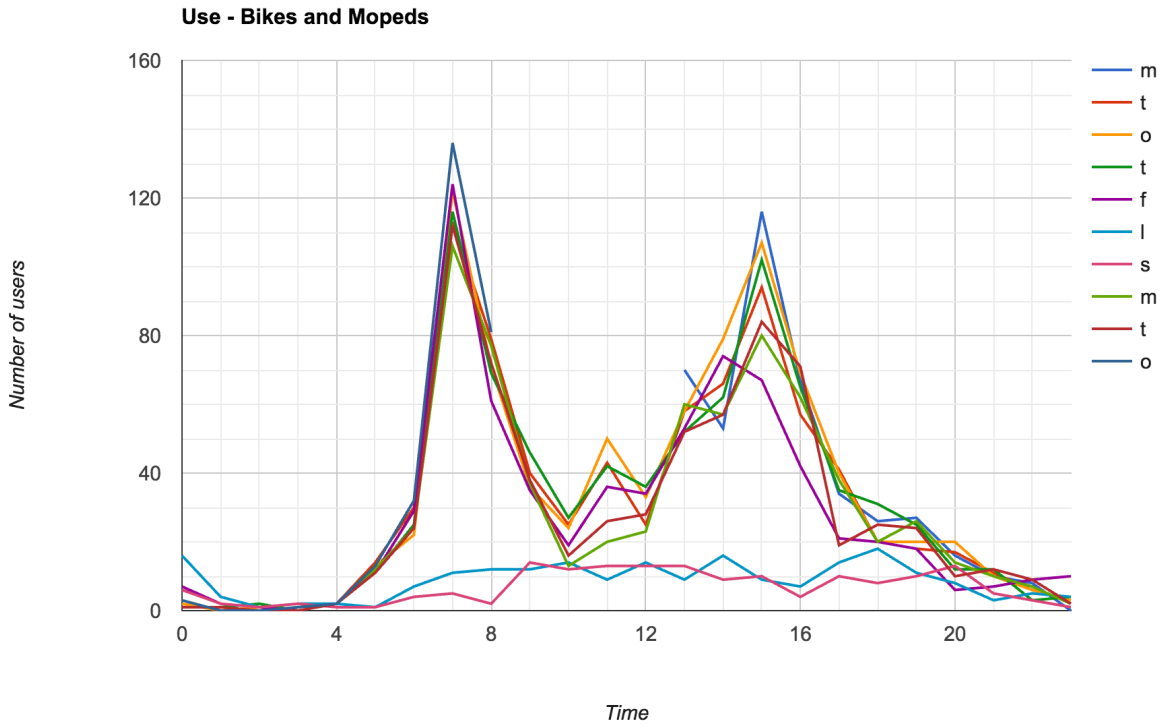
Ill. 05 / The route of the Musicon-path between Roskilde train station and Musicon. Red areas mark busy roads, blue mark residential areas and the green area marks the park. The numbers represent the position of the planned sqaures to be build along the path.



Ill. 06 / Table showing the changing context along the path.



Ill. 07 / Estimated usage pattern of the different user groups.



Ill. 08 / Registered use of the path today of bikes and mopeds. Data collected in the period of 17-08-2015 - 26-08-2015. The graph shows peak usage periods around 7 AM and 15 PM on weekdays.

3.4 ENVIRONMENT

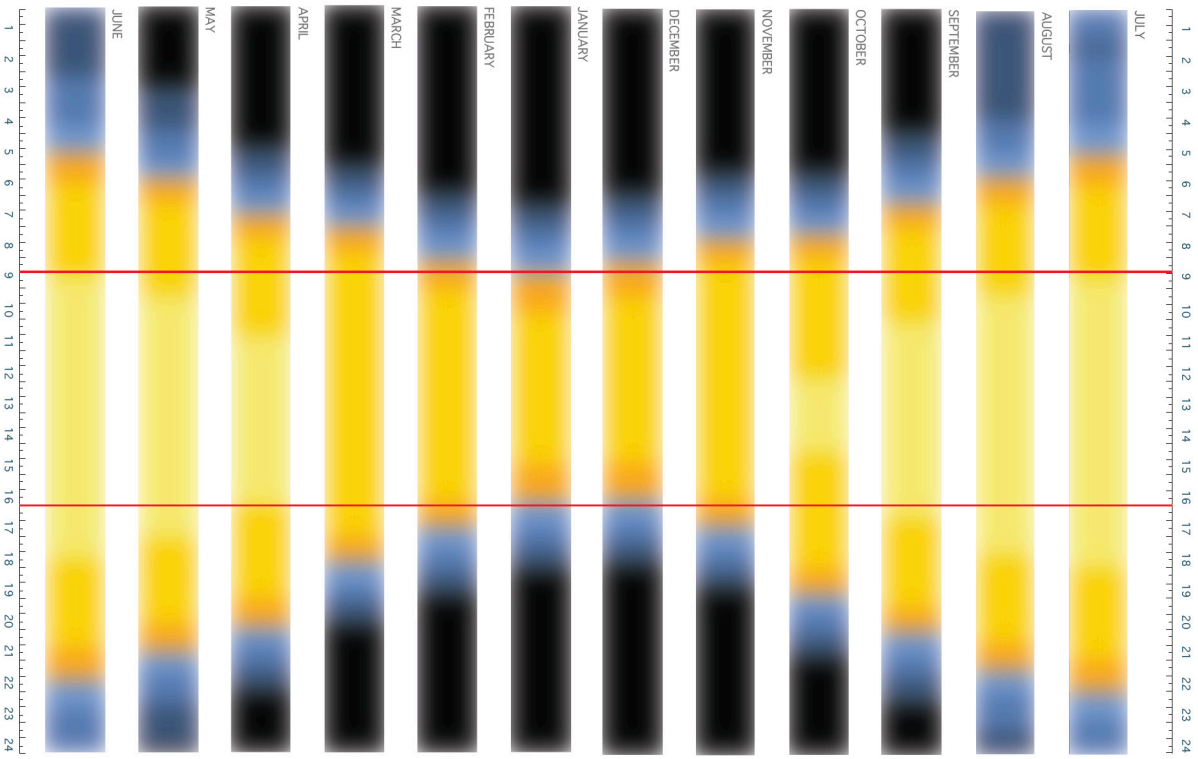
The impression of the lighting design is highly affected by the natural outdoor changes, daily and seasonal. Besides the changings colors of the nature and presence/absence of leaves, flowers and plants, one major effector is the changing light/dark-cycle throughout the year.

The lighting design of the path is going to have the biggest impression in the dark hours, which is why it is important to be aware of when the sun sets and rises over the course of a year.

In her Master Thesis, Winter City Lighting, Sofie Linnebjerg dealt with an exterior lighting design to encourage people to use the city in the winter months (Linnebjerg, 2016). As a part of her analysis she created the graph shown in ill. 09, showing the light/dark-cycle for a year in Copenhagen, Denmark. From this it can be seen that there is a substantial difference in the amount of darkness between i.e. January with eleven hours of astronomical night and June-August where the astronomical night never appears.

3.5 SUMMARY

The information and knowledge gained and presented in this chapter will be used when developing the overall design concept. In short, the main findings here, is the fact that the lighting design at the path needs to act as a transition to and from a creative, lively and sustainable area, it needs to adapt to different contexts with different limitations/possibilities and to be interesting for people using the path every day and show the way for people using the path once a year. Lastly, the lighting design should take the expected usage pattern along with the natural light/dark-cycle throughout the year into consideration.



Night - The night is astronomically speaking period from sunset to sunrise

Astronomical twilight, which lasts until the sun is 18 ° below the horizon

Nautical twilight, which lasts until the sun is 12 ° below the horizon; but can you not discern the outline of the outside, and the brightest stars are visible

Civil twilight, which lasts from sunset until the sun (the sun's center) is 6 ° below the horizon; that's so bright that you can read at a west-facing window

Golden Hour - a period shortly after sunrise or before sunset during which daylight is redder and softer than when the sun is higher in the sky

Solar elevation above 30degrees

Solar elevation above 60 degrees

Ill. 09 / The light/dark-cycle in Copenhagen, Denmark, throughout the course of a year.

4 STATE OF THE ART

To build on the shoulders on proven concepts and thus ensure a thought through context based design, it is valuable to look at the existing knowledge and best practices about urban design, urban lighting and award winning lighting design projects. To ensure that the knowledge gathered is based on different perspective, the literature selected is authored by architects, urban planners, lighting designers, lighting design companies, researchers and directorates. An overview of the reviewed literature and how it is grouped can be seen in ill. 10. The examined sources are:

URBAN DESIGN
Cities for People - Jan Gehl
The Image of the City - Kevin Lynch
The Social Life of Small Urban Spaces - William H. Whyte

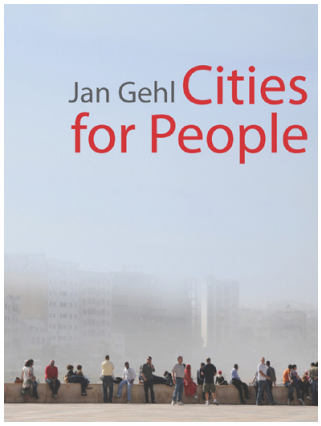
URBAN LIGHTING
Cities Alive: Rethinking the Shades of the Night - Arup
Light for Cities - Ulrike Brandi
Human Factors in Lighting - Peter Robert Boyce
Håndbog Vejbelysning - The Danish Road Directorate
ELSE, Experience of Lighting Sustainability in the Environment - Daria Casciani and Rossi Maurizio

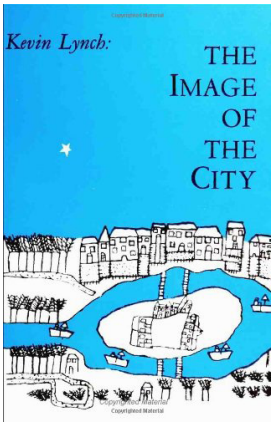
AWARD WINNING PROJECTS
Analysis of recent urban lighting related winners of city.people.light, IALD Design Award and Den Danske Lyspris (The Danish Lighting Award).

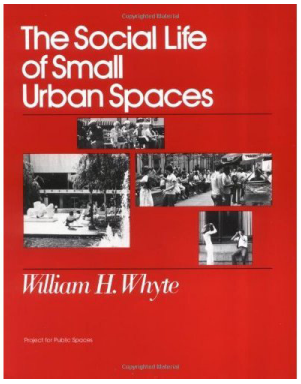
OTHER
Sustainability Issues on LED Lighting - Jessika Luth Richter, LU IIIEE
Talk with Walid Fakousa

The information gathered, will serve partly as an inspiration for the design concept for the Musicon-path and as a foundation for reasoned decision-making about certain design features for the overall concept.

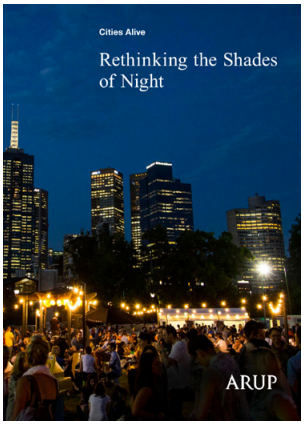
URBAN DESIGN

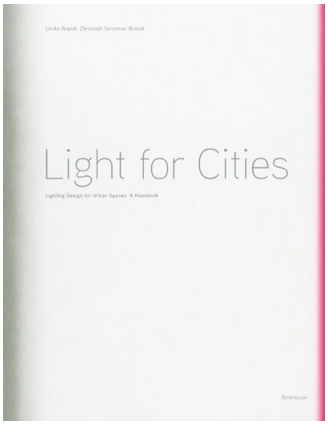


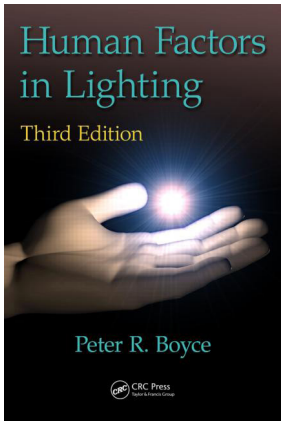




URBAN LIGHTING







Ill. 10 / Front covers of examined written sources.

4.1 URBAN DESIGN

CITIES FOR PEOPLE - JAN GEHL

Jan Gehl is a Danish architect and urban designer. He has spent most of his professional career working on improving the quality of urban life through a human scale design approach.

In his book 'Cities for People' he covers thoughts and principles on how to make cities and urban spaces lively, safe, sustainable and healthy. The common denominator throughout the book is to redesign the city space from a human scale - in contrast to a design for cars.

A great part of the books deals with how to make people use the city space, in which he deals with a concept of 'invitation'. The factors that are responsible for inviting people to use an urban space can be divided into human scale design, usage, physical features and safety.

Human scale:

Jan Gehl explains that:

"[...] working with the human scale means providing good city spaces for pedestrians that take into account the possibilities and limitations dictated by the human body." (Gehl, 2010 - p. 33)

An important point to consider in relation to the possibilities and limitations of the human body, is the 5 km/h speed of which pedestrians often travel. At that speed there is time to take in and experience a lot of details and features of the surroundings. Without any visual stimulation inputs, the walk quickly becomes boring. In the words of Jan Gehl:

"*Five km/h architecture is based on a cornucopia of sensory impressions, spaces are small, buildings are close together and the combination of detail, faces and activities contributes to the rich and intense sensory experience. [...] The 60 km/h scale has large spaces and wide roads. Buildings are seen at a distance, and only generalities are perceived. Details and multifaceted sensory experiences disappear, and from the perspective of a pedestrian, all signs and other information are grotesquely magnified. [...] Taking a walk in 60 km/h architecture is an impoverished sensory experience: uninteresting and tiring." (Gehl, 2010 - p. 44)*

He continuous by explaining the importance of having surroundings with a:

"[...] wealth of detail and information. Walks become more interesting and meaningful, time passes quickly and distances seem shorter. However, where there are no interesting edges to skirt or where ground floors are closed and monotonous, walks seem long and impoverished in terms of experience. The whole process can become so meaningless and tiring that people give up walking altogether. [...] Physiological studies of people in a room with no stimulation show that our senses need stimulation at fairly short intervals of four to five seconds, which appears to ensure a reasonable balance between too few and too many

stimuli." (Gehl, 2010 - p. 77)

Considering the human scale in the urban design can thus help speed up the perceived time and make the distance travelled seem shorter. This effect proves especially important for paths with a length above 500 meters:

"Walks of 500 m are mentioned frequently as a distance most people are willing to walk. However, an acceptable distance also depends on the quality of the route." (Gehl, 2010 - p. 121)

Gehl elaborates further:

"The road is straight and seemingly endless, with no promise of interesting experiences along the way. The prospect is tiring before the walk is even begun. [...] In contrast, the route can be divided into manageable segments, where people can walk from square to square, which naturally breaks up the walk, or along a street that winds enticingly, inviting the pedestrian from one section to the next." (Gehl, 2010 - p. 127)

See ill. 11, 12 and 13.

Physical features:

Besides a detailed human scale design, the physical features of an urban space can be crucial for inviting people to use it. One point that Gehl mentions is to:

"Make sure there's never quite room enough." (Gehl, 2010 - p. 151)

This sounds at first as a bad design parameter, but makes more sense after this explanation:

"The connection between distance, intensity closeness and warmth in various contact settings has an interesting parallel in decoding and experiencing cities and city space. [...] In narrow streets and small spaces, we can see buildings, details and the people around us at close range. There is much to assimilate, buildings and activities abound and we experience them with great intensity. We perceive the scene as warm, personal and welcoming. [...] This is in sharp contrast to the experience in cities and urban complexes where distances, urban space and buildings are huge, built-up areas are sprawled out, details are lacking and there are no or few people. This type of urban situation is often perceived as impersonal, formal and cold." (Gehl, 2010 - p. 53)

So, the point to *"make sure there's never quite room enough"* is to get interesting elements closer to the people, thus creating a more intense, warm and personal experience.

Besides bringing the urban room closer to the observers, it is important to create a design that makes is possible to stay for a while. The impact of doing so can be highly beneficial according to Gehl:

"Squares that combine walking and staying register an activity level of between 10, 20

Scale and Rhythm
The 5 km/h – 3 mph scale, compact and full of interest with narrow units and many doors.
The 60 km/h – 37 mph scale works for drivers on the move, but not for pedestrians.

5 km/h – 3 mph

or 60 km/h – 37 mph scale

Transparency
Walking in the city is enhanced for pedestrians if they can see goods on display and what is going on inside buildings. And that works both ways.

Open

or closed

Appeal to Many Senses
All our senses are activated when we are close to buildings that provide interesting impressions and opportunities.
In contrast, eight posters do not inspire.

Interactive

or passive

Texture and Details
City buildings hold attractions for pedestrians walking slowly. Appealing ground floors offer texture, good materials and a wealth of details.

Interesting

or boring

Mixed Functions
Narrow units and many doors supplemented by a wide variation in functions provide many points of exchange between in and out and many types of experiences.

Varied

or uniform

Vertical Façade Rhythms
Ground floors with primarily vertical façade rhythms make walks more interesting. They seem shorter too, compared to walks along horizontally oriented façades.

Source: "Close encounters with buildings," Urban Design International, 2006.

Vertical

or horizontal

Ill. 11 / Good and bad cases showing how to design (and not) for the human scale.

Ill. 12 & 13 / Examples of flat and large urban areas creating a dull, cold and boring urban space, where few people would like to linger.

and sometimes even up to 30 times higher than transit squares. If lively and attractive cities are the goal, there is every reason to look at staying opportunities and attractions." (Gehl, 2010 - p. 73)

This is why:
"Cities must provide good conditions for people to walk, stand, sit, watch, listen and talk." (Gehl, 2010 - p. 118)

A simple way to invite people to stay is simply to provide an option to sit. As a proof, Gehl refers to a case study from Aker Brygge in Oslo where:

"[...] In 1998 the old benches were replaced by new ones that more than doubled the area's seating capacity (+129%). Surveys in 1998 and 2000 before and after the change show that the number of people who sit in the area has correspondingly doubled in response to the new options (+122%)." (Gehl, 2010 - p. 17)

Having physical features that makes the space interesting and invites to a short stay enhanced the 'optional activities', as Gehl coins it, that makes the space seem alive:

"At one end of the scale are the purposeful necessary activities, that is, activities that people generally have to undertake: going to work or school, waiting for the bus, bringing goods to customers. These activities takes place under all conditions. [...] At the other end of the scale are the largely recreational, optional activities that people might like: Walking down the promenade, standing up to get a good look at the city, sitting down to enjoy the view or the good weather." (Gehl, 2010 - p. 20)

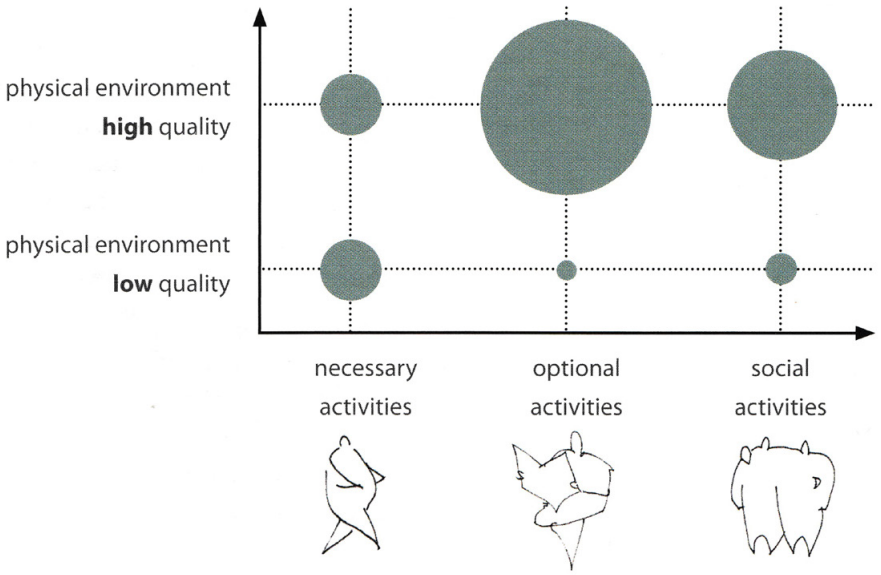
See ill. 14.

Another benefit from having people to stay for a while in the space, is the way it helps increase the amount of life in the city:

"The number of users, the quantity, is one factor, but another equally significant factor for life in the city is the amount of time users spend in public city space. [...] The activity in the visual field is linked to how many other people are present and how much time each user spent at the site." (Gehl, 2010 - p. 71)

People:
The reason why the amount of people in the visual field is important, is due to the self-perpetuating process, that an urban space that succeeds in inviting a few people to use it and stay in it, can benefit from. As Gehl puts it:

"Inviting cities must have carefully designed public spaces to support the processes that reinforce city life. One important prerequisite is that city life is a potentially self-reinforcing process. "People come where people are" is a common saying in Scandinavia." (Gehl, 2010 -



Ill. 14 / Graph showing how improving the physical environment, increases optional and social activities, while necessary activities stay constant.

p. 65)

A reason for this, as he explains earlier in the book, is the fact that:

"Experiencing life in the city is also diverting and stimulating entertainment. The scene changes by the minute. There is much to see: behavior, faces, colors and feelings. And these experiences are related to one of the most important themes in human life: people. [...] The statement that "man is man's greatest joy" comes from Hávamál, a more than 1000-year old Icelandic Eddic poem, which succinctly describes human delight and interest in other people. Nothing is more important or more compelling." (Gehl, 2010 - p. 23)

Safety:

The last, but not least important factor, is safety. The perception of being safe in environment is a high determinator for people to decide if they want to use an urban space or not. A way to make a space to seem safe is, again, linked to the presence of other people and a human scaled design:

"The potential for a safe city is strengthened generally when more people move about and stay in city space. A city that invites people to walk must by definition have a reasonably cohesive structure that offers short walking distances, attractive public spaces and a variation of urban functions. These elements increase activity and the feeling of security in and around city spaces. There are more eyes along the street and a greater incentive to follow the event going on in the city from surrounding housing and buildings." (Gehl, 2010 - p. 6)

In relation to this, Gehl talks about the importance of the social field of vision. He explains that the limit of this field is 100 meter, which is where it is possible to see people in motion. Another significant threshold is 25 meters, where it becomes possible to read and decode facial expressions and the emotion conveyed.

This social field of vision must be supported both day and night, which is why, amongst other factors, a carefully design lighting is important as well:

"Lighting is crucial once night falls. Good lighting on people and faces and reasonable lighting for facades, niches and corners is needed along the most important pedestrian routes to strengthen the real and the experienced sense of security, and sufficient light is needed on pavements, surfaces and steps so that pedestrians can maneuver safely." (Gehl, 2010 - p. 133)

THE IMAGE OF THE CITY - KEVIN LYNCH

Kevin Lynch is an American urban planner and author, dealing with perceptual forms and mental mapping of urban environments. His book 'The Image of the City' is no exception.

The book describes his findings of a five-year long study of Boston, Jersey City and Los

Angeles, describing how observers (the inhabitants) sees the city and draw mental maps (based on five categories: paths, edges, districts, nodes, and landmarks.) of it.

The mental maps reveal how the city is experienced and remembered - and more importantly, what features are needed to create the strongest mental map for each category.

As an introduction to the features for the different categories, Lynch starts out underlining a concept that is equally important for all of them. He states that:

"*Nothing is experienced by itself, but always in relation to its surroundings, the sequences of events leading up to it, and the memory of past experiences." (Lynch, 1960 - p. 1)*

Path requirements

To draw a clear mental image of the paths within a city, the study arrived at four necessary features: Identity, continuity, directional quality and scale.

Identity

Before giving a few pointers on how to strengthen the identity of a path, it is first explained why a clear identity of a path is important:

"Where major paths lacked identity, or were easily confused one for the other, the entire city image was in difficulty." (Lynch, 1960 - p. 52)

Easy identifiable paths may thus be considered as the backbone of the mental image of a city. For a path to achieve a strong identity on it own, Lynch found from his studies that:

"People tended to think of path destination and origin points: they liked to know where paths came from and where they led. Paths with a clear and well-known origins and destinations had stronger identities, helped tie the city together, and gave the observer a sense of his bearings whenever he crossed them." (Lynch, 1960 - p. 54)

Moreover:

"The paths, again, are given identity and tempo not only by their own form, or by their nodal junctions, but by the regions they pass through, the edges they move along, and the landmarks distributed along their length." (Lynch, 1960 - p. 84)

Also:

"Any visual exposure of the path, or its goal, heightens its image. The presence of the path may be made evident by high landmarks along it, or other hints." (Lynch, 1960 - p. 98)

To heighten the identity of a path, to sum up, it is thus important that it is clear where it starts and stops, that it moves along identifiable regions and landmarks, and that its presence is clarified through i.e. landmarks.

Continuity

Besides a clear identity, the path needs to be visibly continuous. Lynch explains:

"That paths, once identifiable, have continuity as well, is an obvious functional necessity. People regularly depended upon this quality. The fundamental requirement is that the actual track, or bed of the pavement, go through; the continuity if other characteristics is less important." (Lynch, 1960 - p. 52)

Directional quality

When the identity and continuity is in place, it is important to consider the directional quality of the path. By this, it is understood that moving in:

"[...] one direction along the line can easily be distinguished from the reverse. This can be done by a gradient, a regular change in some quality which is cumulative in one direction." (Lynch, 1960 - p. 54)

Scale

Related to the directional quality, it should be able for the people using the path to sense their position along the total length of the path and understand the distance traversed and the distance left before reaching the destination. This effect is referred to as the scale of the path.

Lynch elaborates:

"Most often, perhaps, scaling was accomplished by a sequence of known landmarks or nodes along the path. The marking of identifiable regions as a path enters and leaves them also constituted a powerful means of giving direction and scaling to a path." (Lynch, 1960 - p. 52)

And continues:

"A less abstract means is the marking of an identifiable point on the line, so that other places may be thought of as "before" or "after". Several checkpoints improve the definition. [...] Observers are impressed, even in memory, by the apparent "kinesthetic" quality of a path, the sense of motion along it: turning, rising, falling." (Lynch, 1960 - p. 97)

To deal with the fact that paths often are traversed in both directions, in relation to the scale, Lynch proposes that:

"[...] The series of elements must have a sequential form taken in either order, which might be accomplished by symmetry about the midpoint, or in more sophisticated ways." (Lynch, 1960 - p. 114)

...and sums up the concept of scale with the following paragraph:

"The events and characteristics along the path - landmarks, space changes, dynamic sensations - might be organized as a melodic line, perceived and imaged as a form which is experienced over a substantial time interval. Since the image would be of a total melody rather

than a series of separate points, that image could presumable be more inclusive, and yet less demanding. The form might be a classical introduction-development-climax-conclusion [...]" (Lynch, 1960 - p. 99)

THE SOCIAL LIFE OF SMALL URBAN SPACES - WILLIAM H. WHYTE

William Whyte, another recognized American urbanist, organizational analyst and journalist, working on understanding the success criteria for an urban space.

The book 'The Social Life of Small Urban Spaces' sums up sixteen years of research into why certain plazas, mainly in New York, is full of life, while others are empty and seemingly 'dead' spaces.

By the help of a notebook, a group of young observers, and several cameras he mapped a row of successful and unsuccessful plazas, and as a result described the features and principles that will help to create life in an urban setting.

The findings of the study if similar to many of the qualities that Jan Gehl points out in 'Cities for people' including: places to sit, presence of people and intimate surroundings.

Besides these findings Whyte describes how the most used plazas dealt with undesirables - which is, as Gehl mentions about safety, by the presence of other people. Whyte explains:

"The best way to handle the problem of undesirables is to make a place attractive to everyone else." (Whyte, 2001 - p. 63)

He underlines this with a case study of a plaza having problems with criminal activities:

"The exception is a plaza on which pot dealers began operating. The management took away about half the benches. Next, it constructed steel-bar fences on the two open sides of the plaza. These moves effectively cut down the number of ordinary people who used the place, to the delight of the pot dealers, who now had it much more to themselves and their customers." (Whyte, 2001 - p. 63)

A common feature of the successful plazas, is what Whyte refers to as 'triangulation':

"I call it triangulation. By this I mean that process by which some external stimulus provides a linkage between people and strangers to talk to each other as though they were not. [...] The stimulus can be a physical object or sight." (Whyte, 2001 - p. 94)

See ill. 15.

This triangulation is something that adds visual interest, invites people to stay for a while and encourage people to attend in the optional activities that Jan Gehl mentions.

Ill. 15 / Example of a 'triangulation'. Dubuffet's "Four Trees". People touch it, walk under it and talk to each other about it.

4.2 URBAN LIGHTING

CITIES ALIVE: RETHINKING THE SHADES OF THE NIGHT - ARUP

'Cities Alive: Rethinking the Shades of Night' is a report published by the company Arup. It has been written in a collaboration of the 'Foresight+Research+Innovation'-team and lighting team at Arup, with the help of internal and external experts.

The report deals with the tendency of cities being used around the clock and takes a human-centered approach to urban nightlife environments. In other words, it describes how to make most of the dark hours by enhancing the experience and use of public spaces. The overall principle to reach this goal is to take a context-based approach and think the lighting as an integrated part of the urban space in contrast to see it as an added layer. In their own words:

"Cities Alive: Rethinking the Shades of Night explores the future of cities at night, and the role lighting solutions can play in enabling healthy, inclusive and sustainable urban lifestyles. It focuses on the human factor and ways to enhance the experience and use of public space during the hours of darkness." (Arup, 2015 - p. 11)

The 24h city:

The foundation for the report is the increasing number of people living in the city centers and the related increased use of the city space in the nocturnal hours. Its argued that a considered approach to strategic planning and design for the night-time has been missing. It is mentioned that a holistic approach to the urban lighting and an understanding of the importance of the different shades of the night, will help to make up for this missing link. It is further explained that:

"This understanding paves the way for night-time illumination that is more relevant and meaningful to the specific context: bus shelter lighting that improves health and wellbeing of commuters; interactive lighting installations that encourage human interaction; or street lighting that is programmed to enable different levels and types of illumination throughout the night. Such systems go beyond the generic provision of illumination, enabling entertainment, stimulating economic and social activity, and generating vital and vibrant urban environments." (Arup, 2015 - p. 13)

Opportunities:

The recent rapid improvement of new lighting technologies combined with a better understanding of how the lighting affects the human being, results in a couple of opportunities which are listed as:

"- Create intelligent lighting environments that are sensitive to the behaviour of people and responsive to changes in the environment.

- Invest in smart lighting infrastructure that has the capability to be reprogrammed according to future needs and developments.

- Explore the spatial, social, functional and historical context of urban spaces to identify how design opportunities relate to local requirements.

- Consider the diversity of end-user requirements of spaces at night and anticipate a broad range of use patterns in the early stages of projects." (Arup, 2015 - p. 7)

See ill. 16.

In other words, the lighting should be designed and implemented with a clear understanding of its specific context, the behavior of people and an understanding of the impact of lighting on the feeling of safety and health, as discussed later in the report.

Safety:
First of all, for a perception of a safe environment, the physical qualities of the space needs to be in good shape. As it is explained:

"Wilson and Kelling's 'broken windows theory' highlights the importance of a maintained urban environment for combating anti-social behaviour. [...] The more physical dereliction and disrepair is experienced— damaged bikes, litter, or broken street lights—the more likely people are to care less about their surroundings." (Arup, 2015 - p. 29)

The impact of lighting itself on the perceived safety is further discussed:

"*People's perception and feelings of safety in a night-time environment often differ substantially from actual risks. Generally speaking, lit places are safer than dark areas; however, whether light above a certain illuminance further increases the safety of a place is less clear. [...] In fact, overly lit nightscapes can reduce the eye's ability to adapt to darkness and spot danger, especially in areas with varying light levels across adjacent spaces and could subjectively be associated to unsafe places." (Arup, 2015 - p. 30)*

It is argued that:

"[...] rather than seeing lighting as a direct enabler for safety, enhanced illumination should be seen as a means to attract more people to a space, thus creating safety through presence and activity. This highlights that effective lighting for safety requires more than a simple illumination of space." (Arup, 2015 - p. 30)

This implies, as mentioned by both Gehl and Whyte, that the urban space and its lighting should be designed to attract people (and repel the undesirables) and thus, through the concept of 'eyes on the street' coined by Jane Jacobs, improve the feeling of safety (Jacobs, 1961).

Health:
In relation to the health, the report briefly discusses the impact of lighting on the circadian

Ill. 16 / The Nichols Bridgeway - a pedestrian bridge located in Chicago, Illinois, showing a good example of lighting being an integral part of the architectural structures.

rhythm of people:

"While blue light helps people wake up in the mornings, it also suppresses the production of melatonin, a vital hormone for helping us get to sleep at night, [...] warm red light provides the right signals to help us the transition to sleep. [...] In the future, there will need to be a greater focus on the colour of light and its effect on specific spaces and contexts." (Arup, 2015 - p. 43)

Also, besides the color of the lighting:

"Light and darkness are equally important to our health and wellbeing. With the shift towards 24h cities, the value of darkness needs to be reconsidered. We should not aim to simply recreate the day at night, but should carefully consider the role of nighttime lighting, including how much light is required and desirable." (Arup, 2015 - p. 45)

LIGHT FOR CITIES - ULRIKE BRANDI

Ulrike Brandi, a German educated industrial designer, now lighting design practitioner with her own lighting design company, draws on her experience in the book 'Light for Cities'.

Besides describing how to deal with the communication of the technical and planning aspects of lighting design, the books gives a qualitative and somewhat quantitative description of best practice lighting for a long row of urban scenarios, in which two of them fits with this path project.

The first scenario mentioned, quite briefly, is a square in an urban setting. About the lighting here, she mentions:

"The square itself must be sufficiently lit, so that people will want to walk in it and linger in its brighter areas." (Brandi and Geissmar-Brandi, 2007 - p. 72)

The next is more detailed. It deals with the lighting of the illumination of trees in a park. See ill. 17. She writes:

"Most suitable are neutral white halogen metal vapour lamps (HIT). Warm white or sodium-vapour lamps make the tree and its leaves appear grey. If one chooses buried luminaires, it is important not to place them too close to the trunk. The growing roots could displace the fittings, and trees do not like the heat. If the surroundings are dark, a little light is sufficient. When seen from a distance, the subtle lighting of trees in open spaces and parks can be extremely attractive. The site will gain in "depth", the trees will compose the silhouette. Trees planted in clumps can be visually grouped together using low lighting near the ground and thus transpose the design intention of parks or courtyards "into the night"." (Brandi and Geissmar-Brandi, 2007 - p. 76)

In another section of the book, a few considerations about how lighting is subject to both time

Ill. 17 / Illustration showing how lighting up the trees at the borders of a park area can create the feeling of an enclosed and thus more intimate space.

and space is mentioned:

"Principally, the lighting designer moves along a two dimensional design strand. He works with the dimensions of time and space. Artificial light for exteriors is mainly relevant at night. Evenings, mornings and seasonal changes bring many recurring transitional situations. The light shifts. Furthermore, the need for seasonal light arises." (Brandi and Geissmar-Brandi, 2007 - p. 87)

Also, as mentioned in 'Cities Alive: Rethinking the shades of the night', Brandi argues that it is important to consider lighting in a combination with darkness. The one does not exist without the other:

"Well thought-out design, however, is based on darkness, the opposite. It conceives light reciprocally, not glistening, colourful, bright, competing, but as an initialisation into the changing times of day and the seasons. This is not to say that the city should be dark. [...] Anyone designing with light should, at the outset of a project, appreciate the day and night cycles of the site." (Brandi and Geissmar-Brandi, 2007 - p. 87)

HUMAN FACTORS IN LIGHTING - PETER ROBERT BOYCE

Professor Emeritus at Rensselaer Polytechnic Institute in Troy, New York, USA, Peter Robert Boyce has, besides experimental psychology and cognitive science, dealt with the field of lighting in the majority of his professional life. He has conducted research on a long row of lighting related topics such as visual fatigue, the impact of age on vision, safety perception, etc.

In 'Human Factors for Lighting' he covers practically all possible ways humans interact with and are affected by lighting. This includes visual tasks, perception of humans, objects and spaces, comfort, behavior, health, safety and more. All claims backed up by research studies.

Safety:

The chapter of safety deals with the relation between lighting and safety. Boyce starts by introducing the factors that influence the perceived safety:

"People, particularly women, who saw the lighting as being unpleasant, unnatural and monotonous and of low brightness and who had a low level of environmental trust tended to consider the footpath more dangerous. These findings demonstrate that people's assessments of any lighting installation depend not just on the lighting but also on their personality and attitudes. Lighting designers cannot do much about personality and attitudes, but they can do something about the perception of brightness and hedonic tone, although the former is much easier to deal with then the later." (Boyce, 2014 - p. 442)

He continues:

"The reason why spatial brightness appears to be effective in enhancing perceptions

of safety is that to most people, it implies better visual performance. This, in turn, means that it should be possible to see finer details at greater distances which gives more time in which to recognize a threat and to decide and act on an appropriate response." (Boyce, 2014 - p. 447)

As mentioned by Gehl, the perception of safety, thus, is dependent on the ability to read the surroundings and more important the body- and facial language of approaching people. In a following paragraph he states that confident face recognition is not possible beyond 17 meter. Slightly shorter than the 25 meters that Gehl mentions. Boyce refers to a couple of research studies to define actual levels of lighting needed for optimal visibility to support the reading of facial expressions: At 17 meters a semi-cylindrical illuminance of 25 lux is needed. See ill. 18.

Another research study that he refers to *(Boyce, 2014 - p. 448)*, has found that the ratio between the vertical and semi-cylindrical is preferred to be between 1.1 and 1.5 for optimal reading of facial expressions. If a ratio of 1.3 is selected, the vertical illuminance, for optimal readings at 17 meters, should be 33 lx.

However, another study, that is also mentioned *(Boyce, 2014 - p. 449)*, shows that a vertical illumination of 10 lux is sufficient to obtain 90% correct recognition of an approaching person.

Crime:
The actual impact of lighting on crime is not clear cut. As Boyce mentions:

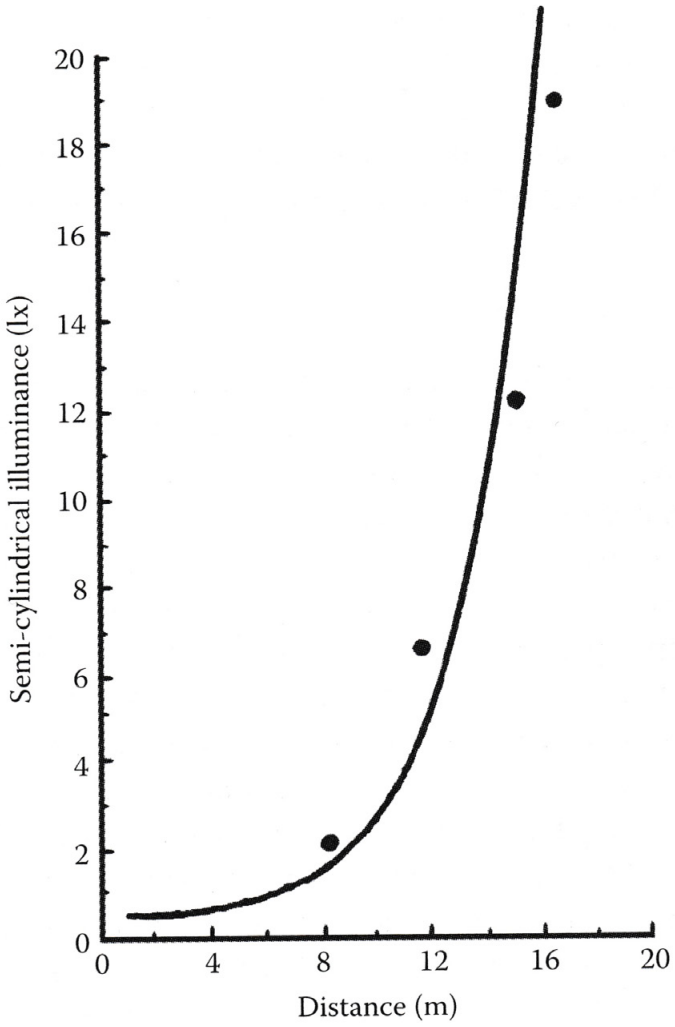
"A series of studies of increasing sophistication leave little doubt that lighting can play a part in crime prevention, but it may not always be effective. There can be no guaranties. This is because lighting, per se, does not have a direct effect on the level of crime." (Boyce, 2014 - p. 485)

This fits well to what is written by both Gehl, Whyte and by Arup, that the lighting is not the direct effector, but rather a mean to attract more people to use the space and thus make it less attractive for criminals to operate in the area.

For optimal surveillance of an area, Boyce mentions a mean illuminance of 10-50 lx, a uniformity ratio above 0.25, a glare rating less than 50 and a good color-rendering is optimal.

Lighting for pedestrians:
In this chapter it is defined which lighting attributes is important for pedestrians in general. It is described that the main objectives for pedestrians is to see where they are, move safely over the ground, assess the risk to personal security, avoid visual discomfort and have something attractive/interesting to look at. *(Boyce, 2014 - p. 456)*

To be able to do so, spatial brightness is mentioned as a factor of importance. Spatial brightness is defined by the level and distribution of illuminances and the light spectrum. While there is no



Ill. 18 / Graph from the mentioned study showing the semi-cylindrical illuminance on the face necessary for completely confident recognition plotted against distance.

clear research on the effect of distribution, the level of illumination and the impact of the light spectrum has been studied. Research shows that the vertical lighting level should be between 10-30 lux and sources with higher S/P-ratio is better. *(Boyce, 2014 - p. 457)*

Light pollution:
A good amount of lighting in an urban space is great. However, if not carefully designed, the lighting can be polluting. Lighting can pollute in three different ways. One is sky glow. This covers all the lighting that is either directed directly towards the sky or reflected from every lit object. The sky glow hinders the ability to see the detailed night sky. The second way that light pollutes is referred to as light trespassing. This covers, for example, the lighting from a street light (with the main purpose of illuminating the street), that enters private homes, and thus, in the worst cases, messes with people's circadian rhythms. The last way mentioned is glare. This is an effect caused by a too high contrast in the luminance pattern, often due to a very bright source of light with a tiny surface area. I.e. an single led, or a single light source against a dark background. *(Boyce, 2014 - p. 570)*

The solution to avoid the different types of lighting pollution, is not to remove the lighting entirely, but to consider it carefully as a part of the design. This includes to analyze when it is necessary for the lighting to be turned on, where it can be positioned and in which direction it can be aimed. As Boyce put it:

"[...] the first question that anyone concerned with purchasing or designing a new outdoor lighting installation should ask themselves is 'Is this lighting necessary and, if it is, when is it necessary?" (Boyce, 2014 - p. 570)

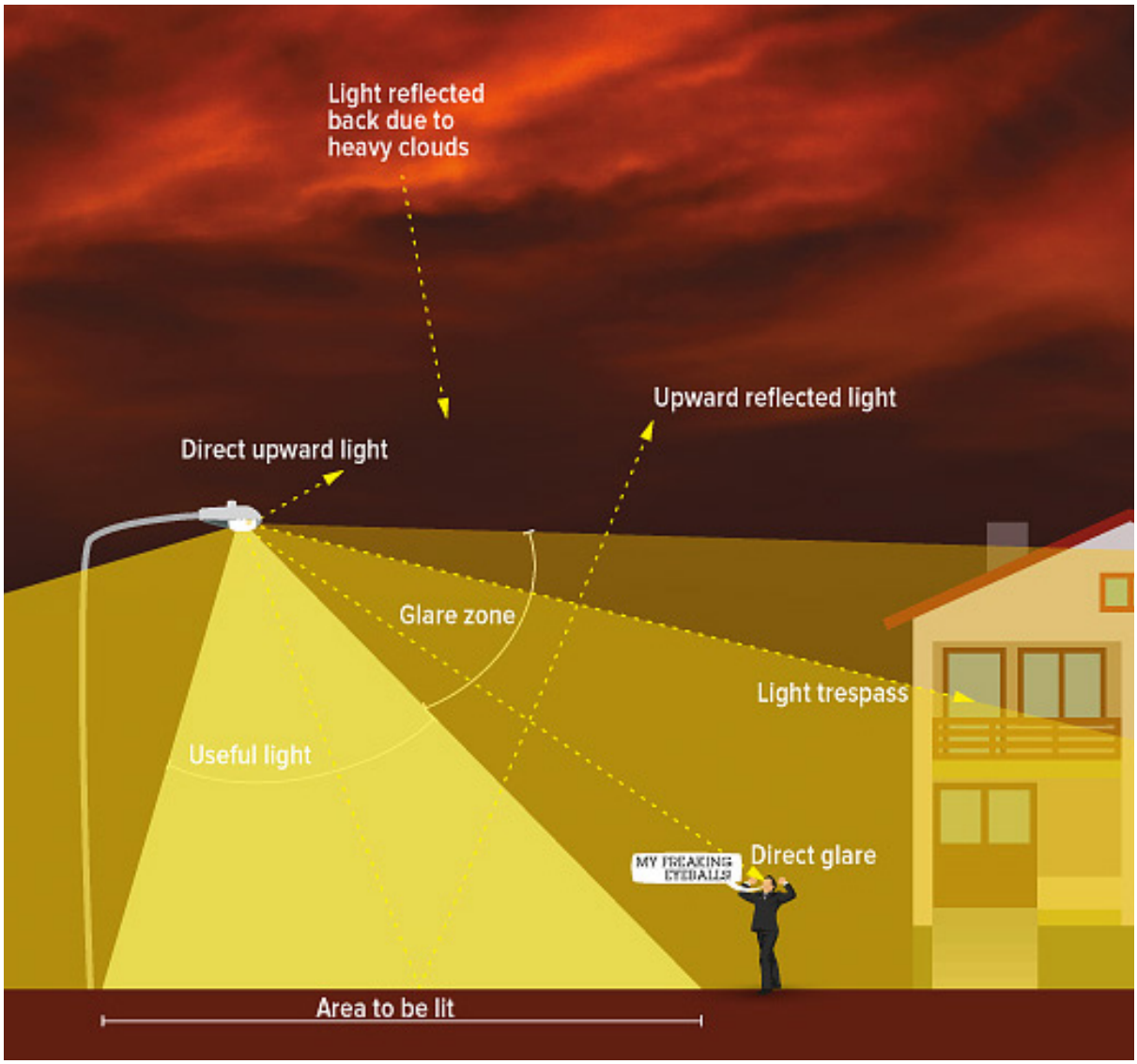
See ill. 19.

HÅNDBOG VEJBELYSNING - THE DANISH ROAD DIRECTORATE
Håndbog Vejbelysning (Handbook road lighting) is a publication from 2015 by the Danish Road Directorate, that contains information about national road lighting regulations and requirements.

The handbook has been developed by a workgroup consisting of lighting designers, engineers, representatives from municipalities and the Danish road directorate, etc.

General thoughts:
The handbook starts out with a few thoughts about lighting and the general role of lighting. All of which are backed up by the findings from the other already mentioned sources. It is stated that the main purpose of lighting is to support security, safety and accessibility, while creating a visually interesting environment that helps give the space an identity and creates moods and experiences. Furthermore, the importance of a careful selection of luminaires is described:

"*Æstetisk flot belysning, med armaturer af høj kvalitet, styrker det centrale bymiljø og*



Ill. 19 / The different types of light pollution.

er med til at gøre byen mere attraktiv for besøgende om aftenen. [...] Belysningsanlæg fylder meget i bybilledet, både hvad angår størrelse og udbredelse i forhold til andet vejudstyr. Det er derfor vigtigt, at vejbelysningsanlæggene tilpasses til vejen, byrummet og omgivelsernes arkitektur, så der opnås et harmonisk hele både set om dagen og med lyset tændt om natten." (Håndbog Vejbelysning, 2015 - p. 8)

Safety and crime:
Although the handbook mainly deals with the level and type of lighting needed for different road profiles, it also covers different specific areas of lighting design. The first one deals with safety and crime related to road lighting. It is mentioned, in the lines of what Boyce wrote, that a certain amount is needed, not only to avoid traffic accidents, but also to induce a feeling of a safe environment for the residents.

The effects that lighting can have on criminality is moreover mentioned. Here, they refer to Dutch and British studies that showed a 20 percent decrease in criminality after an increased level of street lighting, compared to immediate streets with no change increase in lighting.

Light attributes:
A second theme that is mentioned scattered throughout the handbook is specific attributes of the lighting needed for good street lighting. The attributes mentioned are the color temperature, the semi-cylindrical level of illumination and the color rendering index.

In relation to the color temperature it is mentioned that:

"I Danmark (og det øvrige Norden) foretrækkes normalt en varm hvid lysfarve (farvetemperatur på ca. 3000 K) eller neutral hvid lysfarve (ca. 4000 K). Anvendelse af koldt hvidt lys (farvetemperatur på ca. 5000 K eller derover) anbefales ikke til vej- og stibelysning." (Håndbog Vejbelysning, 2015 - p. 56)

Moreover:

"Hvidt lys og god farvegengivelse bør navnlig anvendes på steder, hvor man færdes til fods og har kort synsafstand til vejen, personer og omgivelser. Hvidt lys bør også anvendes, hvor armaturer i lav højde giver pletvis høje belysningsstyrker på belægninger, græs, blomster, løv og bygninger, så farverne ses tydeligt. En naturlig gengivelse af menneskers hud er også vigtig." (Håndbog Vejbelysning, 2015 - p. 12)

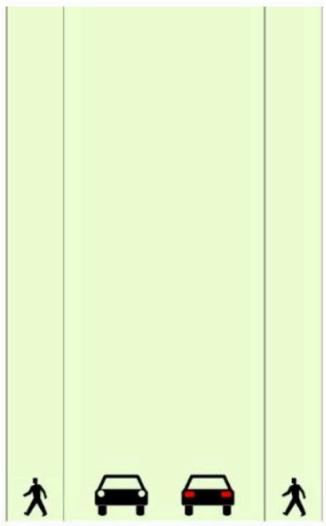
To determine the needed level of semi-cylindrical illuminance, a class of lighting, based on the profile of the specific roads is to be used. See the E-row lighting class, ill. 20.

The E-row, as described in the handbook:

"[...] anvendes på steder, der i det væsentlige belyses af hensyn til fodgængere og cyklister. Disse trafikanter har i højere grad brug for at kunne se enkeltheder og overfladestruktur

Belysningsklasser i E-rækken		E1	E2	E3	E4
Halvrumlige belysningsstyrker på færdselsarealet som helhed:					
Middelbelysningsstyrke, minimum, (driftsværdi) [1)]	E_{hr}, lux	5,00	2,50	1,00	-
Regelmæssighed, minimum:	R	0,15	0,15	0,15	-
Blændingstal for armaturer		Se afsnit 3.4			

[1)] Når minimumkravet til middelbelysningsstyrke har stærkt uheldige konsekvenser for belysningsanlæggets udformning, og der opnås væsentlige fordele herved, kan kravet underskrides med højst 10%.



Krav iht. E-klasse

Lokalvejens beliggenhed	Belysningsklasse på lokalveje
Tæt, høj bebyggelse	E1
Lav eller spredt bebyggelse	E2

Belysningsklasse på stier mv.	
Stier i egentligt færdselsnet	E2
Rekreative stier	ingen krav
Fodgængerområder/gader	minimum E2
Parkeringspladser	minimum E4

Ill. 20, 21, 22 & 23 / Tables showing the E-row requirements and the specification of classes based on the road profile, building density and type of path.

i rumlige genstande, som fx andre personer, fortovskanter, vejbump, gadeinventar samt vejens eller stiens overflade på kort afstand. E-rækken er derfor opstillet på grundlag af halvrumlige belysningsstyrker, der giver et bedre indtryk af lysets evne til at fremhæve rumlig struktur end belysningsstyrken på vandret plan." (Håndbog Vejbelysning, 2015 - p. 20)

From ill. 21, 22 and 23 it is determined that the functional lighting for the path, both in the residential area and the park, needs to comply with class E2. This means that the minimum semi-cylindrical illumination needs to be 2,5 lux with a uniformity of minimum 0.15.

In relation to the CRI, it is mentioned that for local roads, paths, etc. a minimum of 70 is required. *(Håndbog Vejbelysning, 2015 - p. 55)*

Glare and light pollution:
To avoid glare and light pollution, the handbook presents a few clear requirements. See ill. 24. For local roads, paths, etc. the class D5 and D6 is used (*Håndbog Vejbelysning, 2015 - p. 24).* It is furthermore described, again in clear consent with Boyce, that:

"Direkte belysning af haver og fritliggende bebyggelser må søges undgået. Desuden må generende belysning ind i rum i boliger ud til vejen søges undgået." (Håndbog Vejbelysning, 2015 - p. 58)

Vandalism:
To avoid degradation of a lighting design due to vandalism, the handbook also present classes of 'beskyttelsesgrader' (degrees of protection) against external mechanical impact. See ill. 25.

If the light source is positioned in a height of four to seven meters, luminaires with a beskyttelsesgrad IK06 should be used. If the height of the light source is less than four meters, luminaires with a beskyttelsesgrad IK10 is required. *(Håndbog Vejbelysning, 2015 - p. 55)*

Dimming:
In relation to dimming it is mentioned that the classes E1-E4 should be dimmable. In relation to this it is described that it is important to dim all light sources equally, opposed to i.e. turn off every other luminaire, as it will create dark spots and render significantly worse visual conditions. *(Håndbog Vejbelysning, 2015 - p. 60)*

ELSE, EXPERIENCE OF LIGHTING SUSTAINABILITY IN THE ENVIRONMENT - DARIA CASCIANI AND ROSSI MAURIZIO

ELSE, Experience of Lighting Sustainability in the Environment is a paper by Daria Casciani and Rossi Maurizio. It describes an ongoing study about social sustainable lighting.

The paper is build around case studies of several exterior lighting design that has been

Blændingstalsklasse	D0	D1	D2	D3	D4	D5	D6
Blændingstal, maksimum	-	7000	5500	4000	2000	1000	500

IK kode	IK00	IK01	IK02	IK03	IK04	IK05	IK06	IK07	IK08	IK09	IK10
Slag-energi (Joule)	-	0,14	0,2	0,35	0,5	0,7	1	2	5	10	20

Ill. 24 & 25 / Tables of classes for glare and mechanical impact.

analyzed and rated on several parameters. The findings so far show that experiences of social participation, safety perception and energy saving through a meaningful use of interactive and colorful layered lighting effects, is one key to a successful lighting design.

The paper starts out introducing that urban lighting is more than quantifiable numbers and a race to use the least amount of energy:

"Conversely, several studies and recommendation from the CIE (Commission Internationale de l'Eclairage standing for International Commission on Illumination) supported by the lighting design practice, agree that urban lighting is more than energetic statistics about savings and quantitative lighting performances: lighting is primarily intended for people's experience and perception of the urban space and, for this reason, should also consider the beautification of the spaces, the safety and security perception, the establishment of social engagement and well-being of its inhabitants." (Casciani and Rossi, 2012 - p. 2)

This is linked to what already has been covered in many of the previous mentioned sources. Lighting should be applied through a holistic approach and thus provide an feeling of safety, an interesting experience related to the context and invite to social engagement through energy efficient luminaires.

Also, they describe, as mentioned by Gehl, that:

"Urban public spaces should support the social activities of people, creating opportunities for short-term and low-intensity contacts that can contribute to engage people in easy and informal interactions, reintroducing the trust relationship with the other citizens and the city." (Casciani and Rossi, 2012 - p. 3)

From the analysis that they conduct, three projects seem to stand out as being more socially engaging and entertaining than the rest. It is described that:

"They present an interactive use of coloured lighting systems, in addition to the existing traditional lampposts: this extra lighting system defines a pleasant and more complex scene, leaving untouched the readability and the coherence of the space. The arousal is probably favourably enhanced by the unexpected, unconventional and surprising ways of using light within a complex interplay of elements: complexity and richness of stimuli are able to satisfy the human needs of exploration." (Casciani and Rossi, 2012 - p. 7)

These findings is well linked to what Gehl describes about the level of detailing needed for a successful human scaled design. The authors link the findings to other research as well:

"As other researches reveal, in fact, human beings require a balance of unity and complexity in the built-environment in relation to colour and light: the human natural condition is the balance of changing variables and the unnatural condition is the static or too chaotic situation. (Birren, 1983)." (Casciani and Rossi, 2012 - p. 7)

This above paragraph reflects the thoughts by both Arup and Brandi, about the need for a interplay of both bright and dark areas.

Based on the rankings of the different lighting project, the paper also concludes that people prefers designs where the interactive lighting is a meaningful overlayer as an extra element. This concept is linked to another research study that likewise concludes that:

"[...] people prefer lighting schemes with a layered approach constituted of a good general uniform luminance coupled with visual accents and decorative elements (Hargroves, R.A. 2001)." (Casciani and Rossi, 2012 - p. 10)

Another part of the study, based on a ranking of the most desired values of an urban lighting design, placed:

"[...] the safety perception, the energy efficiency and the increasing of social engagement at the top of the list." (Casciani and Rossi, 2012 - p. 11)

The paper ends up with a conclusion that:

"[...] more positive reactions in terms of emotions and behaviours were expressed by people on projects of lighting that shows openness, dynamicity, interactivity and unconventional exploration of the space." (Casciani and Rossi, 2012 - p. 11)

Put in other words, in the most successful designs:

"[...] the use of interactive lighting results in an escapist experience without losing its original mission (seeing, orienting, walking)." (Casciani and Rossi, 2012 - p. 11)

4.3 AWARD WINNING PROJECTS

To uncover potentials for lighting designs, not mentioned in the investigated literature, a qualitative review of recent lighting design award winners has been conducted.

The projects investigated has been awarded in either *LUCI/PHILIPS' city.people.light*, *IALD* or *Den Danske Lyspris* and are related to urban lighting.

Appendix 3 - Award Winning Projects, shows the analysis of 13 projects, while the general findings are presented in the following.

STATE OF THE ART FINDINGS

Although the type of projects described are quite diverse, there seems to be a row of common features that are highlighted as reasons for winning the awards.

LED Sources:

All projects use LED as the main sources of light. It is flexible, programmable and has a low

energy consumption making it the best option for a great range of applications.

Integrated/hidden sources:
Many of the projects are praised for the way the luminaries and sources of light are seamlessly integrated into either the architecture or urban furniture. Illumination is provided without destroying the visual impression of the space, night and day.

Supports and emphasize architectural details:
The lighting added to a space, building, plaza, etc. is carefully thought out. The architectural context is considered heavily and works as an overall framework for the lighting.

Layered approach to interactive lighting:
In most of the interactive installations, the interactive lighting is added as a separate layer on top of the functional lighting. This ensures a lighting design that fulfils the basic needs (visual guidance, feeling of safety, etc.) while providing an concurrent interesting overlay.

Meaningful interaction:
The interactive layers are mostly based on the surrounding context in one way or another. Either by dimming the lighting in a sensitive area when no one is around, utilizing the ambient sound from the city or the speed of the wind in a windy plaza.

See ill. 26.

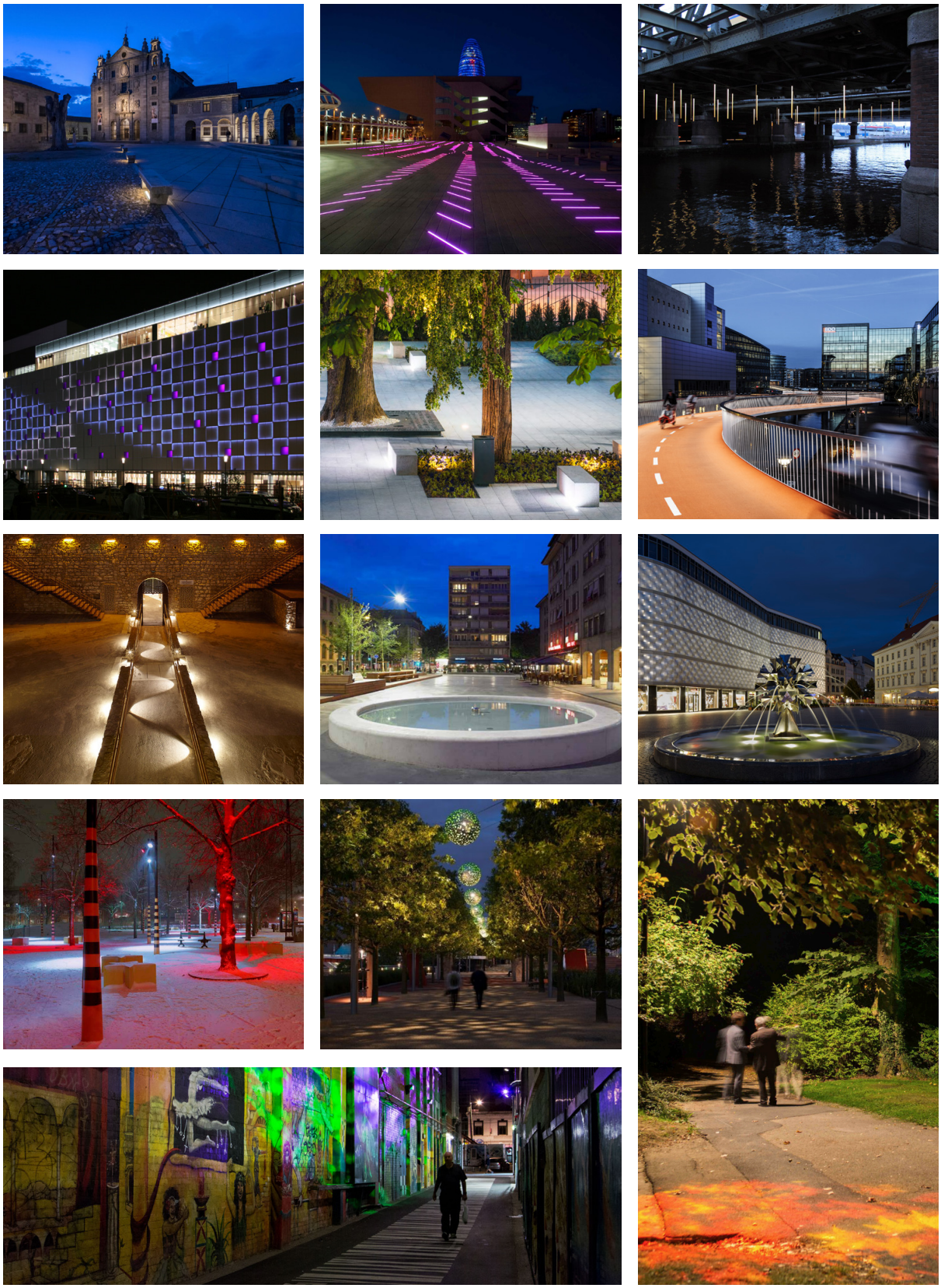
4.4 OTHER

SUSTAINABILITY ISSUES ON LED LIGHTING - JESSIKA LUTH RICHTER, LU IIIEE

As a part of the Lighting Metropolis project, a workshop with presentations from different institutions was held in Lund the 12th of October 2016. One presentation, conducted by Jessika Luth Richter, doctoral student at The International Institute for Industrial Environmental Economics, dealt with the LCA (Life Cycle Analysis) and sustainability issues for LED lighting.

In the presentation, the environmental impact of different stages in the life of an LED source was described. This included the resource use, the impact on human health and ecological impacts. The main takeaway from this presentation was the fact that, on average, 85% of the environmental impact is linked to the use phase. The second largest is the manufacturing stage with a percentage of 2-20%. The environmental impact of the transport phase only accounts for 1-2%.

The presentation was ended by concluding that, based on the above knowledge, the two most significant parameters to the environmental impacts are the luminous efficacy (lm/W) and useful life (hours of operation during lifetime).



Ill. 26 / Images of the 13 examined recent award winning projects

This underlines the importance of using energy efficient sources and considerations about when it is actually necessary to having the lights turned on.

TALK WITH WALID FAKOUSA

In the initial phase the author of this report had the chance to discuss the Musicon-path project with Waleed Fakousa, Senior Associate at the lighting design firm CD+M, in Dubai. Fakousa holds a bachelor degree in architectural engineering and building technology and a master degree in architectural lighting design from the University of Wismar in Germany. He has many successful lighting designs on his CV and has won two middle east lighting design awards in 2014.

The talk was held in an informal setting and was not documented. The main topic discussed during the short talk (approx. 20 minutes) was the importance of the residents of the area. Besides general suggestions for a successful urban area, which all already are covered in the other mentioned sources, Fakousa put a great emphasis on the residents living next to the path in the end close to the train station. He advices to be careful about not disturbing them i.e. through light pollution or by inviting people on the path to stop and stay just outside their windows.

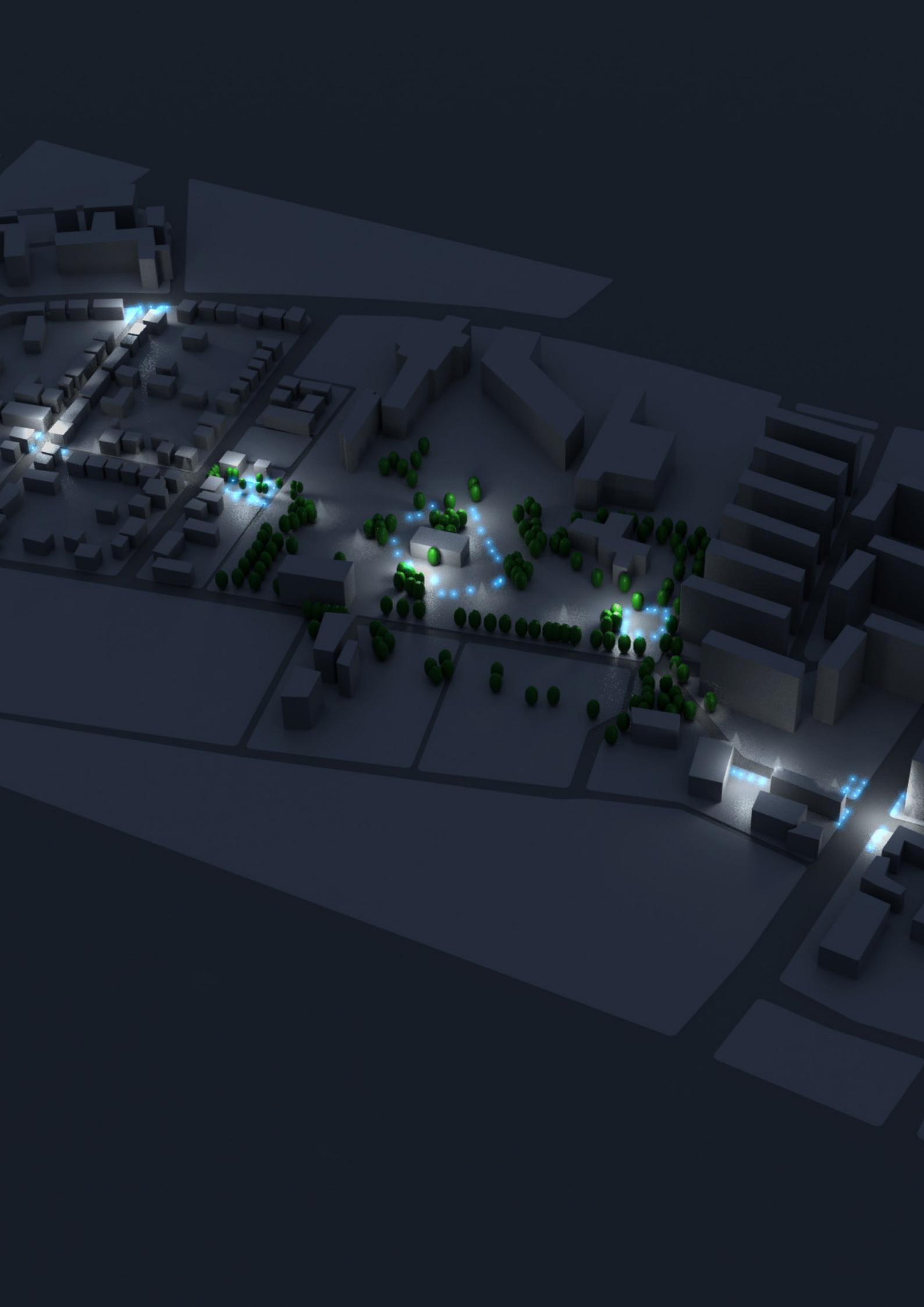
In other words, the design of the lighting should take a holistic approach and carefully adapt to the limitations and possibilities of the surrounding context.

4.5. SUMMARY

Even though written by people with different educational backgrounds and with different agendas, all the examined resources and analyzed projects seems revolve around the same topics of important qualities of an lighting design in an urban setting.

First of all the lighting most serve to create a perceived feeling of safety and security. Secondly, the lighting should have an added layer of interest, preferably dynamic or interactive in a meaningful way. Then it is important that the lighting design adapts to the local context and the possibilities and limitations that it offers. The lighting design should accommodate the changing environment and appreciate the dark/light-cycle and not try to recreate day at night. This also helps to limit energy consumption and light pollution. Lastly, a neutral white color temperature of 3000-4000 kelvin is preferable.

These overall findings are used, together with the goals defined in chapter 2 and the knowledge of the context presented in chapter 3, to develop the overall lighting design concept that is presented in chapter 5.



5 DESIGN CONCEPT

With an understanding the goals of the project, the details of the context and the knowledge collected from different sources of literature and contemporary award winning projects, it is possible to draw up an overall design for the Musicon-path.

The overall design concept is developed to answer the research question, *how to create an innovative, sustainable and context adapted lighting design concept that through coherence, wayfinding and visual interest, invites people to use the Musicon-path*, including the three main goals and the subgoals defined in the project scope. In the following, the specific elements of the design concept is explained, followed by an elaboration on how the design fulfils the goals and subgoals.

5.1 DESIGN CONCEPT ELEMENTS

The overall design consists of four main elements. A theme, layers, interactivity and timing.

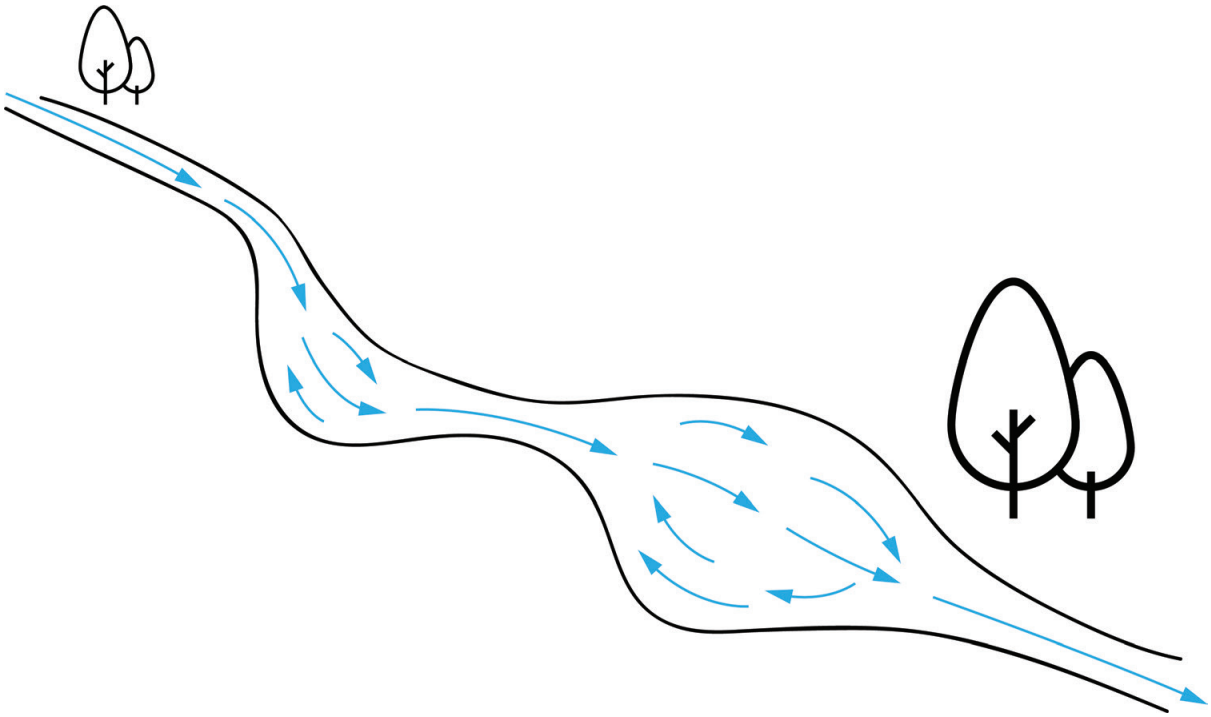
THEME

An overall theme, to create a sense of coherence in the lighting design, and to inspire specific features of the lighting, has been decided upon. The theme is the metaphor of *flow*. Flow as in the physiological sense of the movement of something from one place to another in a steady stream. The theme is partly inspired by the prominence of rainwater in the Musicon district and partly by the goal of wanting the users of the path to walk slow and linger around the squares and move in a normal pace between them. This idea is further strengthen by the observations of Jan Gehl:

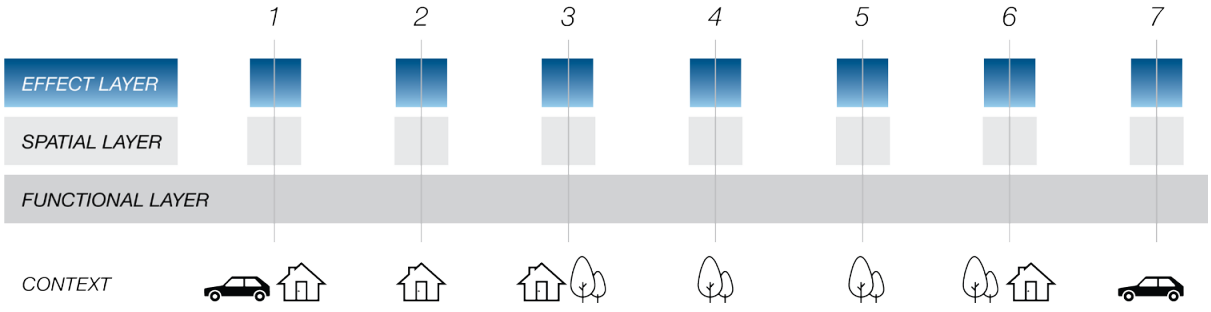
"Pedestrians usually walk faster on street that invite linear movement, while their pace falls while traversing squares. It is almost like water, which flows rapidly along riverbeds but moves more slowly on lakes." (Gehl, 2010 - p. 120)

This quote describes how the water in a river width varying width moves exactly like is wished for the users of the path. See ill. 27. In the narrow parts the water is moving fast while in the broader areas it is moving more slowly.

The contexts that the Musicon-path is running through are, somewhat, already supporting this idea. The park-area, including square four and five is wide and open, while the parts of the



Ill. 27 / Illustration of the flow of water in a river with varying widths.



Ill. 28 / Overview of the seven sqaures and the three layers of lighting. The functional layer is present along the entire path, while the spatial layer and effect layer is only present at the squares.

paths leading up to it are more narrow, thus, at least from Gehl's observations, making people walk slower and linger for a while, in the park, which is optimal. However, it is also wanted to make people slow down at the other squares. Thus, the lighting of the path, on different levels, is designed with this idea of flow in mind and how it can be used to influence the movement of the people using the path. The details are elaborated further in the next section.

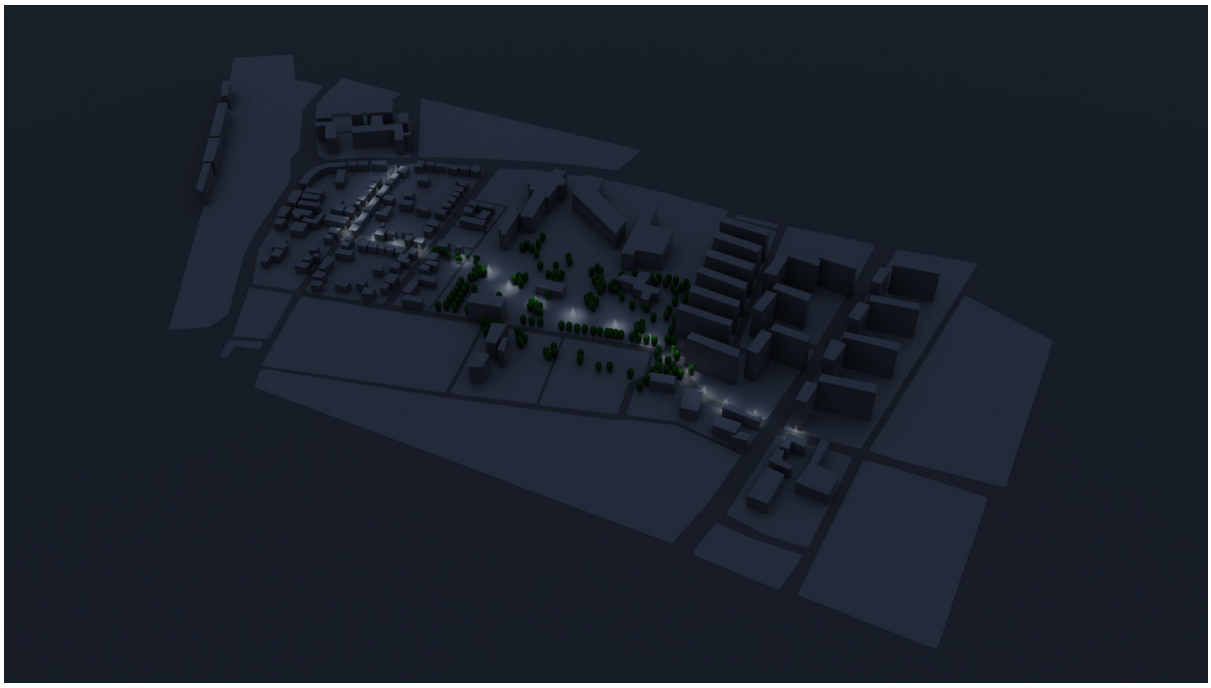
LAYERS

The lighting for the Musicon-path is divided into three layers. A functional layer, a spatial layer and an effect layer. Each of them have different responsibilities. See ill. 28.

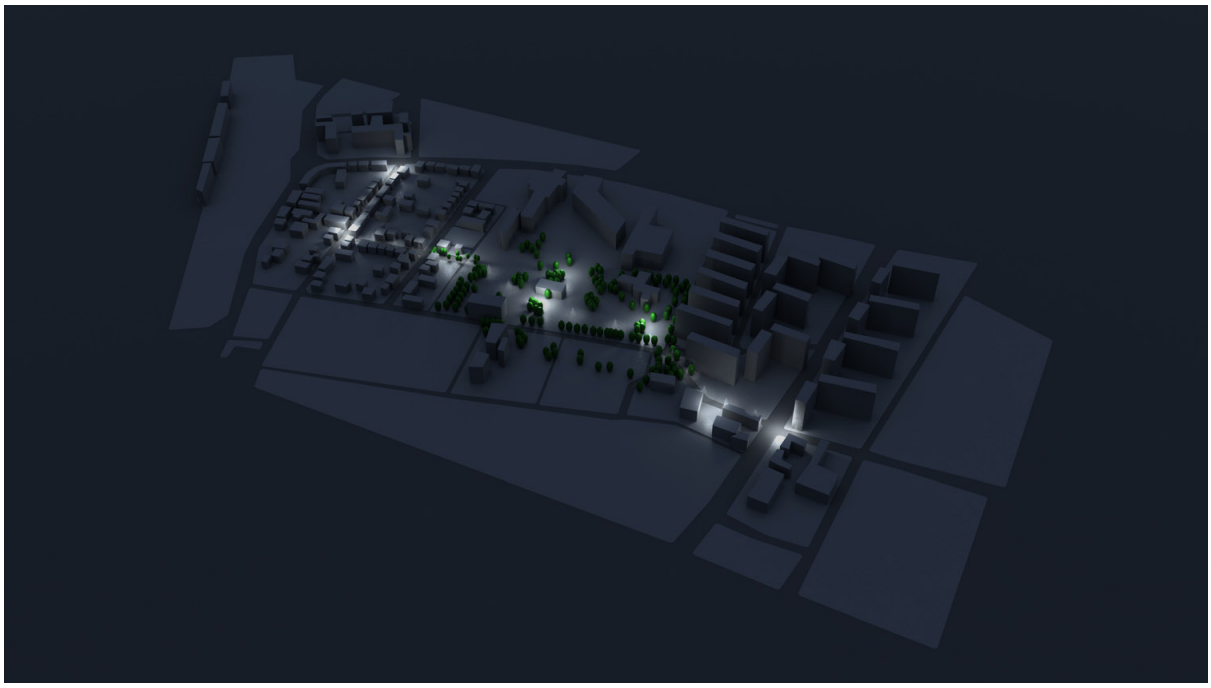
The functional lighting is responsible for providing the minimum levels of lighting for pure functional needs as orientation and the ability to spot i.e. obstacles and cracks in the pavement. The functional layer is present alongside the entire path. Although outside the scope of this particular project, it is expected that the functional lighting complies with the requirements from Håndbog Vejbelysning. That is a semi-cylindrical illuminance of 2.5 lux and a uniformity of at least 0.15. The color temperature, as recommended by Håndbog Vejbelysning, is 4000 K. See ill. 29 for a principal visual representation of the path and the functional lighting.

The purpose of the spatial layer is to provide an enhanced sense of safety at the squares, to make the smaller squares feel more open and in general to create a room of brightness. All means to make the users of the path want to linger and stay for a while around the squares. Based on the research referred to by Peter Boyce, the spatial layer needs to provide a semi-cylindrical illuminance of 25 lux and a vertical illumination of 33 lux. As the functional layer, the color temperature is a neutral white at 4000 K. In ensemble with the dimmer functional lighting between the paths, a sense of flow of brightness is created, adding a hierarchy of important and less important parts of the path. See ill. 30.

The third layer of lighting, the effect layer, is responsible for creating visual interest, act as a dynamic/interactive layer on top of the functional and spatial layer and serve as an easy recognizable element for the sake of wayfinding. How the effect layer is designed and implemented will depend on the context and the ideas of the SME's that are creating the actual lighting design for a specific square. However, to bind the squares together and to create a sense of coherence for the entire path, the effect layer should dynamically and interactive-wise comply with the theme of flow. Furthermore, the color of the effect lightings is going to be similar along the entire path. The color of the effect lighting is decided to depend on the amount of rain at a given moment. The idea is to strengthen the theme of flowing water and enhance the experience of the nature in an urban setting. When it is not raining, the color is a light desaturated blue and as the rain intensifies the color turns gradually to a deep saturated blue. Ill. 31 illustrates the different levels (based on the cumulus software: http://wiki.sandaysoft.com/a/Rain_measurement) and corresponding colors described through hue, saturation and



Ill. 29 / Principal visualization of the path with functional lighting only.



Ill. 30 / Principal visualization of the path with functional and spatial lighting.

brightness. Also see ill. 32 showing a visual of the path with all three layers of lighting included.

The light sources used for all three layers of lighting should be LEDs. This will allow for the needed flexibility in terms of dimming and color-changes and physical integration in the contexts as found as a common parameter in the award-winning projects.

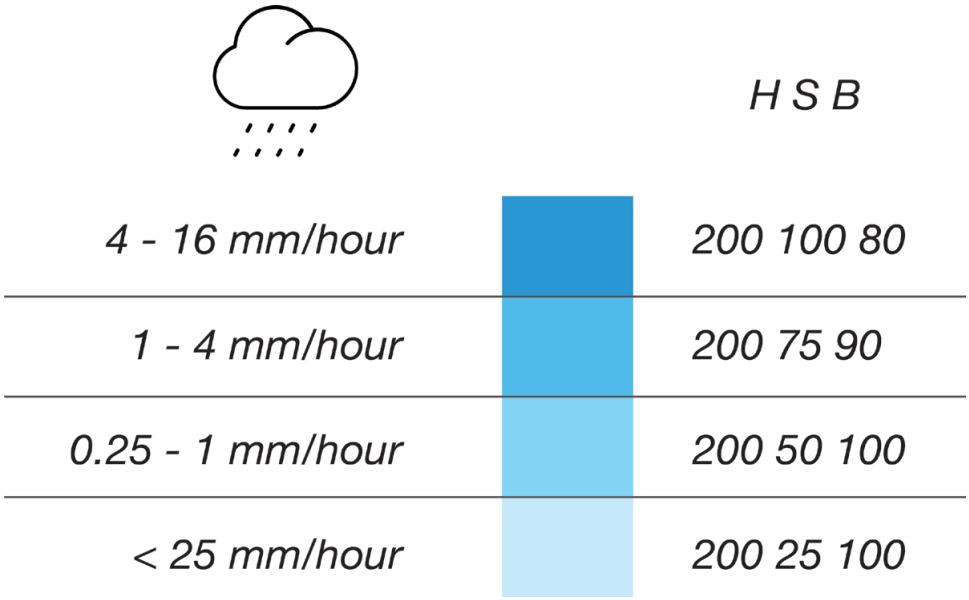
INTERACTIVITY

To help create a playful and lively atmosphere along the path, that invites people to use it, the lighting is dynamic and interactive at the squares. To avoid a Tivoli-like look and to meet the needs of the different contexts, the level of dynamics and interactivity is varied along the path. Also, it only applies to the effect lighting layer.

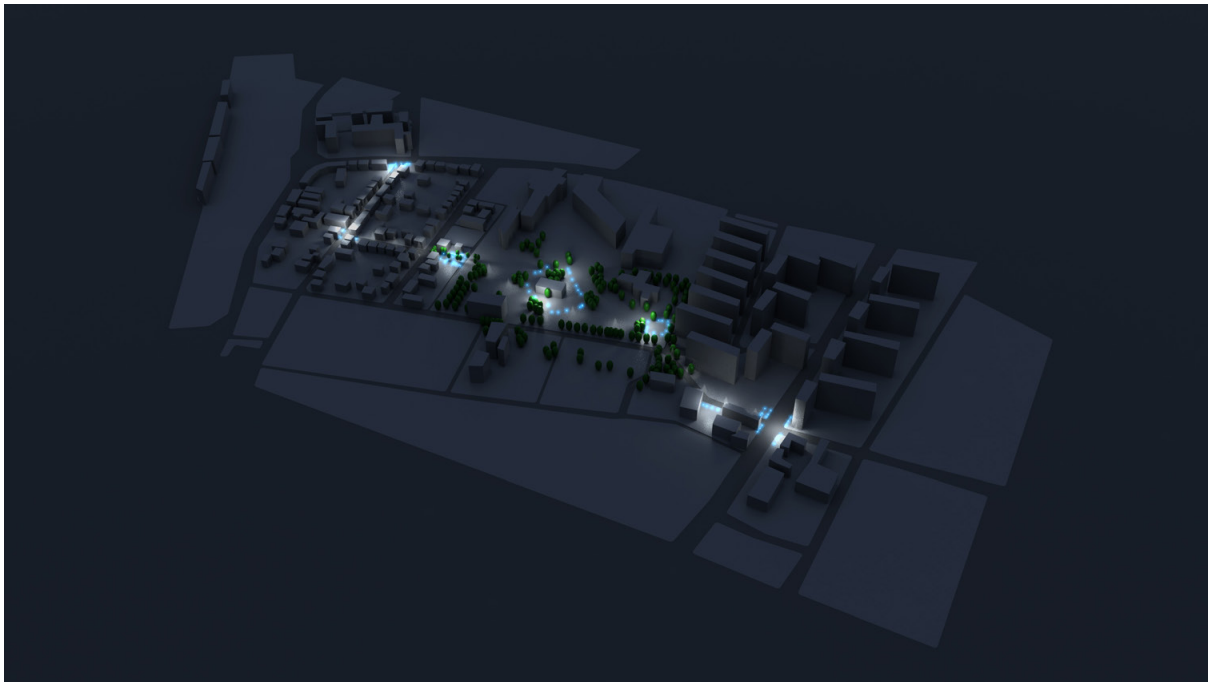
The level of interaction is graphically presented in ill. 33. At square 1, 2 and 7, where the path runs along roads with heavy traffic and through residential areas, the lighting is only subject to ambient interaction. That is, that the color of the effect layer changes according to the amount of rain at any given moment. At square 3,4,5 and 6 the lighting, besides reacting to the ambient color interaction as well, is dynamic. That is, that it moves slowly, pulses, etc. (in the theme of flow) to create visual interest and a sense of life, that makes people want to slow down. If applied in a linear manner, pulsing along the path in the direction of the users with a speed slower than 5 km/h, research (presented in chapter 6) suggest that people will walk slower than their natural walking speed. Additionally, at square 4, the effect layer is directly interactive, thus responding in real time to the movements of the users of the pump-track. If no one is using the pump-track, the effect lighting here idles at the pre-programmed dynamic setting.

TIMING

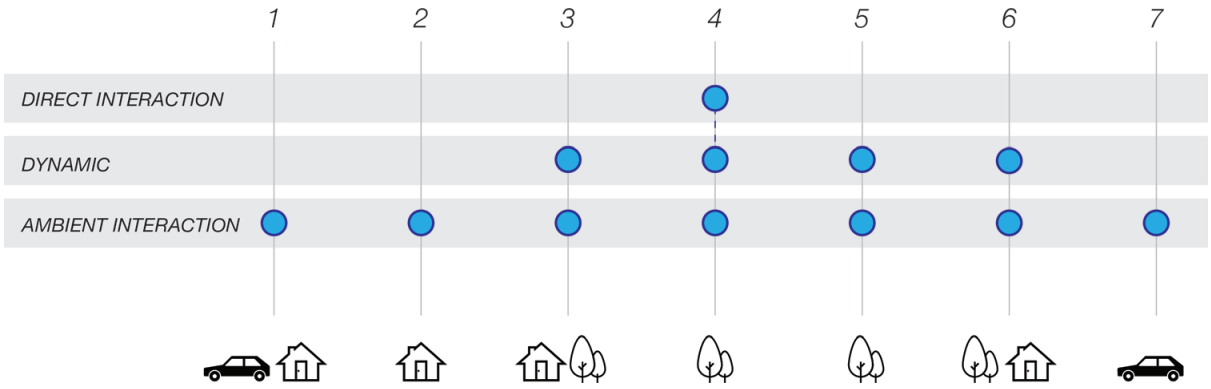
In consideration of minimizing the use of energy and cutting down on the lighting pollution along the path, a dimming and on/off cycle of the three layers of lighting has been defined. Ill. 34 shows a graphical representation of the settings. The spatial and effect layer is linked, while the functional lighting has its own setting. All three layers are on at full from civil twilight (just after sunset) until 1 am, where the use of the path is expected to be low. Here, the spatial and effect layer is turned completely off, while the functional lighting is dimmed to 50% as recommended by the Håndbog Vejbelysning. At 6 am all layers turn on fully until the time of sunrise. In the months where the sunrise occurs before 6 am, the functional lighting is turned off at sunrise and the spatial and effect layer stays off. All three layers turns back on at sunset.



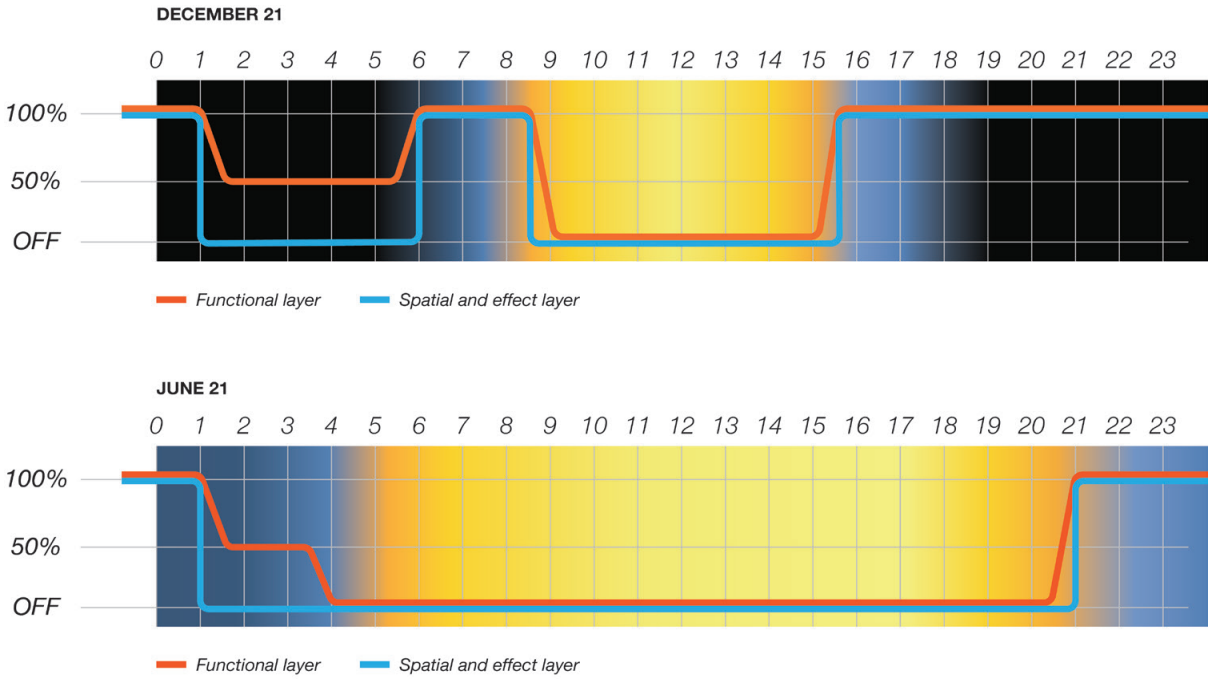
Ill. 31 / Correlation between the amount of rain in a given moment and the resulting color of the effect lighting.



Ill. 32 / Principal visualization of the path with functional, spatial and effect lighting.



Ill. 33 / The degree of interaction at the seven squares.



Ill. 34 / Examples of the timing of the differnt layers during a whole day.

5.2 GOALS

The goals and subgoals defined in the scope are used as initiators to elaborate further on the reasoning for the design choices for the overall concept design.

1. INVITE PEOPLE TO USE THE PATH

Guide people along the path:

Some users of path, as described in the chapter 3, will only walk the path once a year or even less. For this group, to be invited to use the path, it is crucial that the path lighting guides them in the right direction. This is partly why the effect lighting layer is introduced. By the presence of blue colored lighting at each square, the rare visitors can use this as a trail of breadcrumbs to follow.

Invite people to stay and play at the squares:

The combination of the functional lighting and the spatial lighting is one factor used to invite people to stay in and around the squares. The bright surroundings enables a safe environment in which it feels comfortable to linger. Furthermore, the interest added by the effect layer will give people something visually interesting too look at while at the squares.

Give the path an identity on its own:

From the findings done by Kevin Lynch in 'The Image of the City', a path is given identity by a clear connection to its destination, by being visually exposed and having easy recognizable landmarks along them.

The connection to Musicon is made through the dynamic and interactive effect layer. Keywords that can be used to describe this layer are coinciding with the keywords used to describe Musicon, i.e. creativity, play and experimentation as mentioned in chapter 3. In a subtler way, a connection to Musicon is also made through the theme of flow and color changes depending on the rain, linked to the prominence of rainwater in Musicon.

The path is visually exposed both through the brighter squares, and especially by the blue effect layer. At intersections of the path with Køgevej and Søndre Ringvej respectively, the blue lightning will attract attention for the pedestrians and people on wheels, and thus clearly mark the starting points of the path.

The pump-track with the directly interactive effect lighting will be a clear landmark along the path, helping to give the Musicon-path the reputation and identity of being an interactive and playful path.

Make the path feel short:

One way to make the path feel short, is to make it interesting. That is to design it for the human

scale by making sure that there are enough details and features to keep the mind excited and busy along the path. This is done through the dynamic and interactive effect layer that, at varying degrees, will give visual interest while walking and biking.

Another concept, as explained by Lynch, is scale. Scaling is a sequence of landmarks or sections along the path. The spatial layer is used to enhance this effect of scaling. It clarifies the flow of squares and provides a kinesthetic quality that will help the people using the path to feel their progress along it.

Be interesting to a diverse user group:
Some people will walk or bike the path everyday, while some will use it once a year or less. The lighting for the path is made interesting through the effect layer. It will be visually interesting and exciting for the people rarely using the path. However, the novelty and excitement will quickly fade for the people using the path everyday. To make up for this, the color of the effect layer has been made ambient interactive and thus, vary from day to day depending on the amount of rain. It will never provide the same level of interest experienced by the rare users, but will provide a little communication with nature that some daily users hopefully will appreciate.

Adopt to several spatial and functional contexts:
The amount of dynamics and interactivity for the effect layer has been planned around the specific contexts at the squares. At square 1,2 and 7 the level is low, to not distract the drivers on the busy roads and to make sure not to disturb the residents living just next to the squares. In the more open areas and park related contexts at square 3,4,5 and 6, the effect lighting is more dynamic and even directly interactive at square 4 where no one will be disturbed or distracted by the lighting.

2. BE INNOVATIVE THROUGH THE USE OF EXISTING TECHNOLOGIES IN NEW WAYS
Besides using the amount of rain to change the color of the effect layer, the real innovative part of the lighting design is the way the dynamic lighting can be used to influence the walking speed of people. The research, findings and possible applications is explained further in chapter 6.

Work as a living lab:
This hasn't been addressed directly in the design concept. To work as a living lab, the lighting along the path should be re-programmable and adjustable in several ways. As a minimum it is expected for the luminaires used for the specific lighting design at the squares, that they are dimmable, that the color can be changed and that the luminaires can be addressed individually.

How to connect the lighting hasn't been investigated in depth, but the fixtures chosen for the specific lighting designs at the squares needs to be connectable via a standard protocol like DALI, DMX or wirelessly over i.e. ZigBee.

Be able to notificate about events at Musicon:

Through the same requirements needed for the lighting design to work as a living lab, it will be possible to notificate about events at Musicon. A solution to do this could be to link the color of the effect layer to a common calendar containing the planned events at Musicon. This way it will be possible to define that for certain event, the color of the effect lighting along the entire path should overwrite the rain-setting and show another predefined color.

3. BE SUSTAINABLE

For the path lighting to be sustainable, considerations about the energy use and environmental impact has been made. The lighting is designed to be synchronized with the changing day/night-cycle throughout the course of the year, saving energy and minimizing lighting pollution in the area. Furthermore, by the advice to use LED sources, it is expected that the luminous efficacy is high while keeping the maintenance low. The luminaires selected should furthermore be designed for outdoor use and comply with the recommended degree of protection described in Håndbog Vejbelysning.

6 RESEARCH

6.1 INTRODUCTION

In relation to the overall lighting design for the Musicon-path presented in the previous chapter, it is relevant to investigate whether it is possible to alter people's walking speed unconsciously by the use of a layer of animated 'moving' lighting.

That humans are directly and indirectly affected by their surroundings is no secret. A great body of research exists on many different influences on people's behavior. One large influence on people's behavior, is other people. An effects known as the 'chameleon effect', describes how people in a social environment unconsciously mirrors each others body languages, facial expressions, etc. (Chartrand and Bargh, 1999). Besides other people, it seems that everything that can be captured by the basic human senses, in one way or another, influences behavior. For example, scent proves to be an effective influencer. Several studies has investigated how the introduction of different scents in different environments affects mood and decision-making. In the book 'Brainfluence' by Roger Dooley, three studies are presented:

"Scents can affect perception in other ways, too. In one experiment, two pairs of identical Nike shoes were evaluated by consumers: one in a room with a floral scent and one with no scent. Fully 84 percent of the subjects evaluated the sneakers in the scented room as superior." (Dooley, 2012 - p. 36)

"One experiment showed that nightclub patrons danced longer when the venue was scented with orange, peppermint, and seawater. When surveyed, the patrons of the scented clubs reported they had a better time and liked the music more." (Dooley, 2012 - p. 37)

"A test in a casino found that people gambled 45 percent more money in a slot machine when a pleasant scent was introduced into the area." (Dooley, 2012 - p. 37)

Also sound (and music), just as scent, can be used to impact humans in different ways. Studies shows that:

"Music can influence purchasing by changing the speed of movement inside a store and therefore the amount of time spent shopping. The speed at which people walk around a store tends to increase or decrease with the tempo of background music: moderately paced music (less than about 70 bpm) encourages consumers to spend more time (and more money) than faster music. Similarly, the speed at which people eat and drink increases with the tempo

of music." (Clarke, Dibben and Pitts, 2010 - p. 103)

Lighting do also influence and alter the behavior of people. One study shows that when faced with the choice of moving through two hallways, the one brighter than the other, the brighter one is prefered (Ginther, 2004). Another study shows that people tend to position themselves in a space depend on the luminance distribution. Generally speaking, people like to stand in less illuminated areas facing brighter areas (Ginther, 2004). Also, just like scent, the lighting can affect shopping behavior by altering the mood and self-perception of shoppers (Areni and Kim, 1994; Baumstarck and Park, 2010)

Three studies that deals with the effect of lighting on walking speed and movement has been found. However, none of them is directly related to the theme of this research; the effect of 'moving' lighting on people's walking speed. One investigates how the amount of light is related to the time spent 'escaping' an open office environment in an emergency setting (Boyce, 1985). Another investigate the walking speed of miners while wearing two different headlamps (Patts, Sammarco and Eiter, 2014). The third investigates how much time test subjects spends reaching out for an object 30-40 cm away in different lighting color settings (Chen and Huang, 2016).

In the search for existing projects dealing with movements of intensities across light sources, no directly related projects have been found as well. What has been found are three projects, where the lighting is influenced by the people, but not the other way around. One is an installation used by runners in Søndermarken, Copenhagen (Hedegaard, 2011). Here, runners can, at the start of the path, chose a speed they want to run, and a corresponding color of lights moves along the path, through light sources, at the chosen speed. The second project found, an underpass in the city of Kolding, where colored lights on the wall appears when one enters the underpass and follows the person until they exit the underpass (Kollision, 2014). The third is a lighting research project dealing with a square in the city of Aalborg, where, in one setting, the lighting intensity of the light sources is higher closest the person traversing the square (Poulsen et al., 2012).

Although directly related research and projects haven't been found, it is still, based on the knowledge that people certainly are affected by their immediate surroundings in many ways, relevant to believe that 'moving' light can influence the walking speed of people. The specific research question investigated in the following, is formulated as:

Can a row of lights with animated intensities, along a path, affect people's walking speed?

6.2 METHOD

To investigate if a row of lights along a path with animated intensities can affect people's walking speed, the following test has been designed and executed.

PROCEDURE

In short, the test consists of three main elements: A path with functional lighting, a row of lights with animated intensity and people walking on the path. 4 scenarios have been tested:

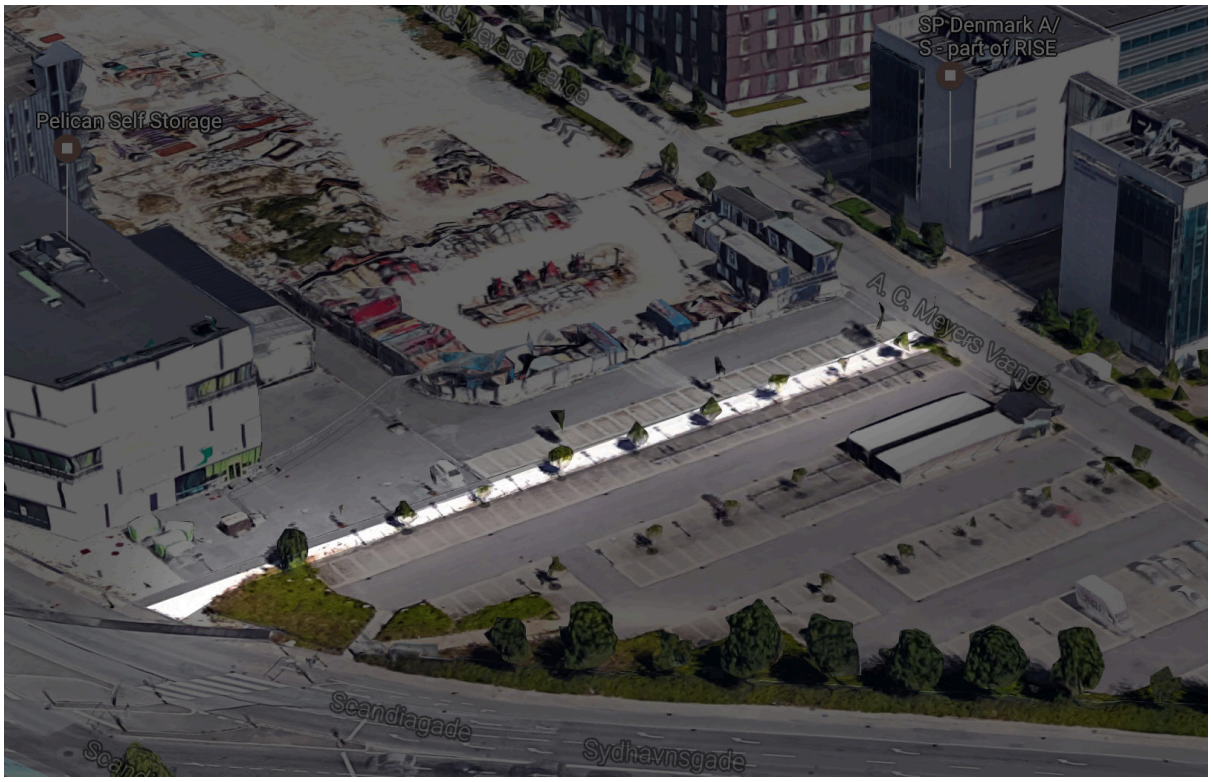
1. No effect lighting - control group
2. Intensity peak moving at 3.8 km/h (in the same direction as the walking people)
3. Intensity peak moving at 6.8 km/h (in the same direction as the walking people)
4. Intensity peak moving at 6.8 km/h (in the opposite direction of the walking people)

All scenarios are registered with video and for each of them, an average walking speed is calculated based on the video data. For step 2-4 an average walking speed before the lights and alongside the lights is registered and calculated. By comparing these results, it is possible to obtain information about whether the 'moving' lighting affects the walking speed not.

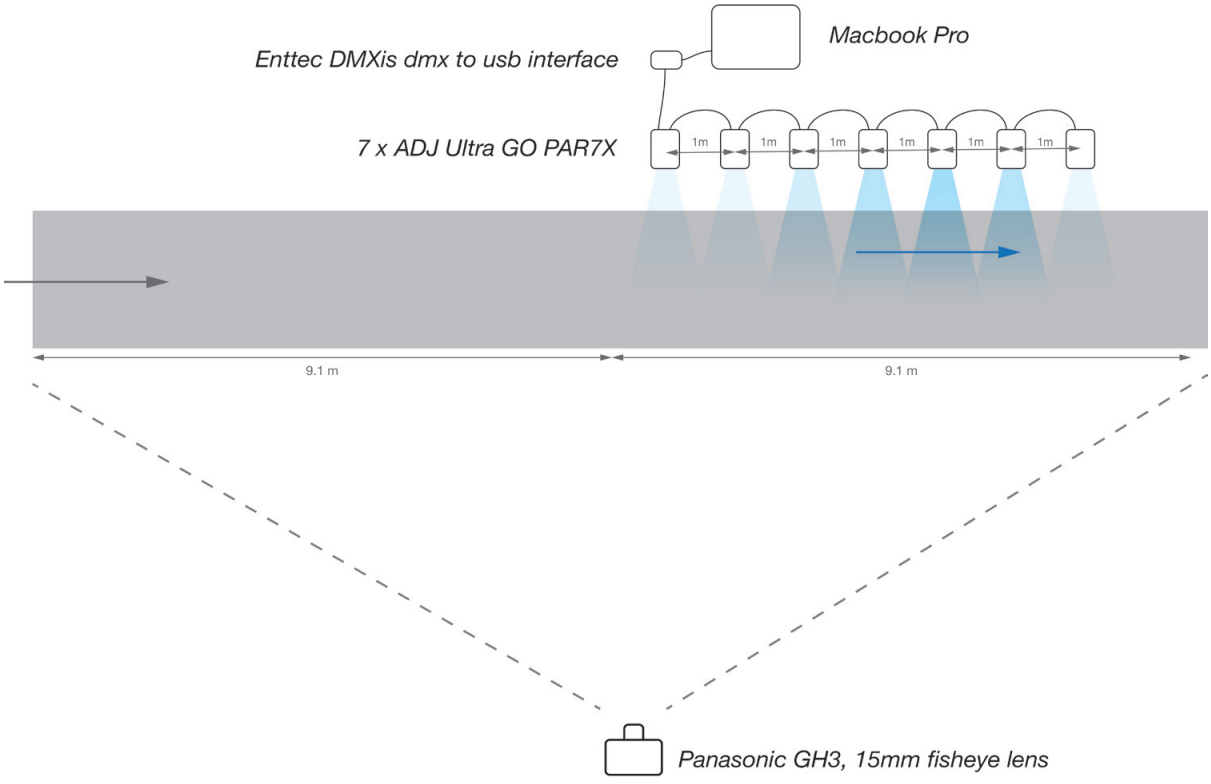
SITE

The site used for the testing was selected based on several criteria. First of all, to get a decent sample size, the site needs to have a substantial amount of flow of people. Second of all, the path should be narrow to make people walk close to the lighting (without being obstructed by the lighting equipment) and long enough to make people obtain their natural walking speed before reaching the section with the lights. Also the path should be continuous with no exit points halfway or close to the section of registration. Thirdly, the camera equipment used for the registration should be placed discreetly, not to make people aware that they are test subjects. Fourthly, the functional lighting should be dim enough, to render the effect lighting clearly visible.

Based on the above criteria, the site selected is the path between the main entrance of AAU CPH and the intersection of Scandiagade and Sydhavnsgade. See ill. 35. It has a decent flow of people, it is narrow and long (approximately 1.3 meter wide and 90 meter long) and the lighting equipment used for the test can be placed just besides the path. The path can be exited and entered at any point, but because of its location and immediate surroundings, the people using the path has little incentive to do so. The camera can be placed discreetly across the nearby parking lot. The path is equipped with lamppost with a spacing of 9.1 meter, providing indirect functional lighting on the path.



Ill. 35 / The path used for the test.



Ill. 36 / Test setup diagram

EQUIPMENT
The equipment used for the testing:

7 x ADJ Ultra GO PAR7X
Enttec DMXis dmx to usb interface
Enttec DMXis dmx controller software
Apple Macbook Pro, mid 2015
Panasonic GH3 camera with 15mm fisheye lens
Adobe Premiere Pro

The 7 ADJ Ultra GO PAR7X's are daisy chained via 1.5 meter DMX cables and positioned next to each other, one meter apart. The lights are connected to a Macbook Pro through the Enttec DMXis dmx to usb interface. The Enttec DMXis dmx controller software, running on the MBP, is used to control the lighting. See ill. 36.

CONTROL OF LIGHT
The ADJ Ultra GO PAR7X's are all set in channel mode 2. This makes it possible to control the color of the light through channel 1 and dimming through channel number 2. In The DMXis software, all color channels are set to 116, resulting in deep blue color referred to as 'Tipton Blue' in the manual for the ADJ Ultra Go PAR7X. In the software, the dimming channels are all selected at once and are animated using the 'Oscillator'' feature. This makes it possible to make the intensity peak move smoothly along the connected lights with certain speeds. The following settings are true for scenario 2-4. Type: Sine, Amount: 50%, Chase: 1, Speed: 2 bars, Shape: 50%. See ill. 37.

Systematic experimentation shows that with the settings above for the seven lights and a speed of 67.5 BPM, the intensity peak moves from one light to the next in one second. This means that, if the lights are placed one meter apart, the intensity peak moves at 1 m/s (3.6 km/h). This knowledge is used to calculate the BPM needed for the peak to move at 3.8 km/h and 6.8 km/h.

*3.8 km/h = 1.06 m/s, 1.06 * 67.5 = 71.3 BPM*
*6.8 km/h = 1.89 m/s, 1.89 * 67.5 = 127.5 BPM*

As it is only possible to input whole numbers in the DMXis software, 71 BPM and 128 BPM are used.

Ill. 37 / DMXis interface.

Ill. 38 / On site test setup.

DATA COLLECTION

The data used to calculate the walking speed of people for the four scenarios are registered with the camera filming at 25 frames pr. second. Registrations took place on the 24/11, 28/11, 29/11 and 30/11 2016 between 4 pm and 5 pm. See test setup in ill. 38.

Afterwards the actual testing, the recorded footage was loaded into Adobe Premiere Pro. Here, a known distance of the sections, measured on site, one before the effect lighting and one alongside, is marked on the footage. For each test subject, the enter-frame and exit-frame for the marked sections are noted (people moving in the opposite direction as wanted for the specific scenarios are neglected). By subtracting these and dividing by 25 frames pr. second, the time spent walking the distance is revealed. From here the walking speed is calculated by dividing the distance of the section, in meters, with the time spent walking the distance. Appendix 4 - Data Registrations, shows all collected data and resulting walking speeds for the four scenarios.

TEST SUBJECTS

The test subjects used were the people leaving AAU CPH in the timespan mentioned above. The subjects were both male and female with an estimated age-span ranging from 20-70 years. They were unaware that they participated in a test setup. The data in scenario 1 is based on 45 participants, scenario 2 on 35, scenario 3 on 44 and scenario 4 on 53 participants.

6.3 FINDINGS

The results based on the captured data for all four scenarios are presented below.

Scenario 1 - No effect lighting, control group, 45 test subjects:
Average walking speed: 5.28 km/h

Scenario 2 - Intensity peak moving at 3.8 km/h (in the same direction as the walking people), 35 test subjects:
Average walking speed before effect lighting: 4.94 km/h
Average walking speed alongside effect lighting: 4.85 km/h

Scenario 3 - Intensity peak moving at 6.8 km/h (in the same direction as the walking people), 44 test subjects:
Average walking speed before effect lighting: 5.20 km/h
Average walking speed alongside effect lighting: 5.48 km/h

Scenario 4 - Intensity peak moving at 6.8 km/h (in the opposite direction as the walking people), 53 test subjects:

Average walking speed before effect lighting: 5.08 km/h
Average walking speed alongside effect lighting: 5.15 km/h

The findings show that the walking speed for the control group averaged at 5.28 km/h. When the intensity peak of the effect layer moved at 3.8 km/h, the walking speed alongside the lighting dropped to 4.85 km/h. When the intensity peak moved at 6.8 km/h, the walking speed alongside the lighting increased to 5.48 km/h. By calculating the average walking speed of the control group and the two scenarios, along with the sample standard deviation and sampling distribution standard deviation, a z-value is derived. From the z-value it is determined that both results are statistically significant with $p < 0.01$ for the slow setting and $p < 0.05$ for the fast setting.

The average walking speed before the lighting in scenario 2 is statistically significant as well compared to the control group, but there is no significant difference compared to the average walking speed alongside the lighting.

For scenario 3, the average walking speed before the lighting was statistically indifferent from the control group. However, the difference between the average walking speed before and alongside the lighting is statistically significant.

The average walking speed, both alongside and before the lighting, with the intensity peak moving opposite the walking direction, showed to have no statistical significant effect compared to the control group.

6.4 DISCUSSION AND CONCLUSION

Although the changes in the average walking speed are not huge, they are still significant and suggest that you can influence the walking speed of people through lighting. The difference between the average walking speed alongside the lighting in scenario 2 and 3 is 13%. This implies that the answer to the research question, *"Can a row of lights with animated intensities, along a path, affect people's walking speed?"*, is "*yes*".

The findings suggest that to make people walk slower, they should walk alongside an intensity peak moving slower than the natural average walking speed. Likewise, the findings suggest that walking alongside an intensity peak moving faster than an average walking speed will make people walk faster.

The fact that there is found no significant difference in the average walking speed when walking alongside an intensity peak moving in the opposite direction, suggests that the peak needs to move in the same direction of the people walking to have any effect.

Despite the found positive relation between the movement of the intensity peak and the average walking speed, it is possible that a row of unknown factors can have skewed the results. The test setup was quite limited and was done in an uncontrollable environment. It is therefore suggested that re-creating a set of similar experiments in a controlled setting with lights spanning over a greater distance, is needed to verify and expand the findings of this initial research.

If further research shows the same findings, the contexts, in which this lighting design principle can be applied, is many. It could be used in park areas similar to the Musicon-path, alongside long paths in general, where it, for different reasons, would be beneficial to slow down or speed up walking people, i.e. in airports, hospitals, supermarkets, etc. It might also be useful at events, festivals, besides large queues, etc., where influencing the speed of which people walk could be benefitial.

6.5 IMPLEMENTATION

To clarify how this new obtained knowledge can be used in relation to the lighting design of the Musicon-path, an example is provided in the following.

Square 3, planned to be a green and plant filled area by the size of 10 by 40 meters, has been selected for the example. See ill. 39. The square can be seen as a transition from the narrower residential context to the open park for the people coming from the train station moving towards Musicon. The purpose of the square is thus to provide a transition from the subtle ambient interactive effect lighting at square 2 to a directly interactive lighting at square 4. Moreover, to enhance the level of life in the park area and to invite people to take a break and enjoy the elements of the park, the effect lighting should invite people to slow down.

The lighting at square 3 consists, as presented in chapter 5, of 3 layers. A functional layer lighting up the path itself, a spatial layer that brightens up the space for enhanced feeling of safety and an dynamic effect layer.

The spatial layer is imagined to light up the four trees at the entrance of the square closest to the residential context, together with an illumination of the hedges, to create a visual border around the space, making a intimate and welcoming feeling.

The effect layer, with the purpose of acting as a visual interesting element as well as slowing down people, is expected to consists of a row thin vertical bollards, scattered along the edges of the path, in between the plants. See ill. 40. The bollards are connected and an intensity peak is moving from one bollard to the next with a speed of 3.8 km/h towards the park.

This setup, however, only affects the people moving from the residential area into the park. If

Ill. 39 / Square 3 and its immidiate surroundings.

Ill. 40 / Square 3 implementation example sketch.

needed, a more advanced setup can be made by introducing a couple of presence detecting sensors at each end of the square. If installed, it will be possible to detect from which direction people are approaching the square and the lighting can be programmed to adjust accordingly. If people are coming from the park towards the residential area the effect lighting can move in the same direction at a speed of 6.8 km/h to speed up people. When people are coming from the residential area towards the park, the movement of the intensity peak will shift to the same direction and move at 3.8 km/h to slow people down.

7 Conclusion

The main goal for this master thesis project was to develop an overall design concept for the Musicon-path. The research question and subgoals presented in chapter 2 and below, were the main targets for the development:

How to create an innovative, sustainable and context adapted lighting design concept that through coherence, wayfinding and visual interest, invites people to use the Musicon-path?

1. Invite people to use the path
- *a. Guide people along the path*
- *b. Invite people to stay and play at the squares*
- *c. Give the path an identity on its own*
- *d. Make the path feel short*
- *e. Be interesting to a diverse user group*
- *f. Adopt to several spatial and functional contexts*

2. Be innovative through the use of existing technologies in new ways
- *a. Be able to notificate about events at Musicon*
- *b. Work as a living lab*

3. Be sustainable

To answer the research questions and the subgoals in the best possible way, several analyses were conducted. One analysis focused on the context of the project area on different levels. Furthermore, to build upon existing knowledge about urban design and urban lighting, a literature review of papers, publications and books was made and the main findings were presented. Also, a state of the art analysis of recent award winning urban lighting design concepts were conducted along with talks with lighting design professionals and participation in lighting design relevant workshops.

With the collected body of knowledge, combined with an understanding of the project related context and the goals defined together with the client, it was possible to develop an overall design concept for the Musicon-path that answers the research question. An innovative, sustainable and context adapted lighting design concept that through coherence, wayfinding and visual interest, invites people to use the Musicon-path can be created through the use of

four elements: A theme, layers, interactivity and timing. The theme is the concept of flow which helps to create a sense of coherence and adds variability along the path. The layers contain a functional-, spatial- and effect-layer. The functional layer provides the needed lighting on the path itself, the spatial layer enhances the feeling of safety and intimacy, while the effect layer adds wayfinding and a visual interest. The effect layer is interactive and dynamic at different degrees depending on the specific contexts at the specific squares. The dimming and on/off-cycle of the lighting is synched with the changing day/night-cycle throughout the course of a year, thus minimizing energy use and light pollution.

Besides developing a context specific design concept for the Musicon-path, a second part of this master thesis revolved about research, generating new knowledge within the field of lighting design. The research investigated if it is possible to influence the walking speed of people using light through the question: *Can a row of lights with animated intensities, along a path, affect people's walking speed?* The small scale test showed positive results that suggests that it is possible to influence the walking speed of people using a moving peak of intensity. This knowledge can be implemented in the specific design concept and is also potentially interesting for a row of other applications as well.

The presented overall lighting design is on a conceptual level. Therefore, the next natural steps are to concretize the design decisions and become more precise on a row of parameters including selection of luminaires for the functional lighting along the entire path, physically based visualizations and calculations of the squares to define the actual needed level of light from the spatial layer, and a detailed analysis and plan describing how the lighting should to be connected and programmed to fully work is a living lab in the future.

8 REFERENCES

Areni, C. S. and Kim, D. (1994) 'The influence of in-store lighting on consumers' examination of merchandise in a wine store', *International Journal of Research in Marketing,* 11(2), pp. 117–125. doi: 10.1016/0167-8116(94)90023-X.

Arup (2015) *Rethinking the Shades of Night*. London.

Baumstarck, A. and Park, N.-K. (2010) 'The Effects of Dressing Room Lighting on Consumers' Perceptions of Self and Environment', *Journal of Interior Design*, 35(2), pp. 37–49. doi: 10.1111/j.1939-1668.2009.01037.x.

Boyce, P. R. (1985) 'Movement under emergency lighting: the effect of illuminance', *Lighting Research and Technology*, 17(2), pp. 51–71. doi: 10.1177/14771535850170020401.

Boyce, P. R. (2014) *Human Factors in Lighting*. 3. ed. Edited by P. R. Boyce. Boca Raton, Fla. : CRC Press.

Brandi, U. and Geissmar-Brandi, C. (2007) *Light for Cities*. Edited by U. B. Licht. Birkhäuser - Publishers for Architecture. doi: 10.1007/978-3-7643-8263-6.

Casciani, D. and Rossi, M. (2012) 'ELSE , Experience of Lighting Sustainability in the Environment', *Cumulus Helsinki Conference*, (May 2004), pp. 1–14.

Chartrand, T. L. and Bargh, J. a. (1999) 'The chameleon effect: the perception-behavior link and social interaction.', *Journal of personality and social psychology*, 76(6), pp. 893–910. doi: 10.1037/0022-3514.76.6.893.

Chen, C.-F. and Huang, K.-C. (2016) 'Effects of Background Lighting Color and Movement Distance on Reaching Times Among Participants With Low Vision, Myopia, and Normal Vision', *Perceptual and Motor Skills,* 122(2), pp. 518–532. doi: 10.1177/0031512516640392.

Clarke, E., Dibben, N. and Pitts, S. (2010) *Music and Mind in Everyday Life*. Oxford University Press.

Dooley, R. (2012) Brainfluence : *100 ways to persuade and convince customers with neuromarketing*. Wiley.

EFFEKT (2016) EFFEKT — *ROSKILDE STATION AREA Masterplan and infrastructure 2016*. Available at: http://www.effekt.dk/work#/ros/ (Accessed: 8 December 2016).

Gehl, J. (2010) *Cities for People*. Edited by J. Gehl. Washington. D.C. : Island Press.

Ginther, D. (2004) 'Lighting : Its Effect on People', *Implications,* 2(2), p. 5. Available at: http://www.informedesign.org/.

Håndbog Vejbelysning (2015).

Hedegaard, J. (2011) *Fang lysharen på ny løberute i Søndermarken - Byliv | AOK*. Available at: http://www.aok.dk/byliv/fang-lysharen-paa-ny-loeberute-i-soendermarken (Accessed: 8 December 2016).

Jacobs, J. (1916-2006). (1961) *The death and life of great American cities the failure of town planning.* Penguin books.

Kollision (2014) *KOLLISION : project : INTERFERENCE*. Available at: http://kollision.dk/en/interference (Accessed: 8 December 2016).

Linnebjerg, S. (2016) *Winter City Lighting.* AAU CPH.

Lynch, K. (1960) *The image of the city.* Edited by K. Lynch. Cambridge Mass. : M.I.T. Press under the auspices of the Joint Center for Urban Studies.

Naturstyrelsen, M. (2013) *Fingerplan 2013*. Edited by Naturstyrelsen. Miljøministeriet.

Patts, J., Sammarco, J. J. and Eiter, B. (2014) 'Measuring the effects of lighting distribution on walking speed and head pitch with wearable inertial measurement units', *IEEE Transactions on Industry Applications*, 50(2), pp. 1483–1489. doi: 10.1109/TIA.2013.2272713.

Plan og Udvikling (2015) *MUSICON - Den Musiske Bydel Handleplan 2016-19*. Roskilde.

Poulsen, E. S., Andersen, H. J., Jensen, O. B., Gade, R., Thyrrestrup, T. and Moeslund, T. B. (2012) 'Controlling urban lighting by human motion patterns results from a full scale experiment', *in Proceedings of the 20th ACM international conference on Multimedia - MM '12.* New York, New York, USA: ACM Press, p. 339. doi: 10.1145/2393347.2393398.

Schifferstein, H. N. J., Talke, K. S. S. and Oudshoorn, D. J. (2011) 'Can ambient scent enhance the nightlife experience?', *Chemosensory Perception,* 4(1–2), pp. 55–64. doi: 10.1007/s12078-011-9088-2.

Whyte, W. H. (1980) *The social life of small urban spaces / by William H. Whyte.* 7. printin. Edited by W. H. Whyte. New York : Project for Public Spaces.

ILLUSTRATIONS

Illustration 01: Own illustration. Credit: Esben Oxholm.
Illustration 02: Credit: Roskilde Municipality
Illustration 03: EFFEKT (2016). Roskilde St. [image] Available at: http://www.effekt.dk/work#/ros/ [Accessed: 8 December 2016]
Illustration 04: EFFEKT (2016). Roskilde St. [image] Available at: http://www.effekt.dk/work#/ros/ [Accessed: 8 December 2016]
Illustration 05: Own illustration. Credit: Esben Oxholm. Map data: Google
Illustration 06: Own illustration. Credit: Esben Oxholm. Road profile illustrations, credit: Roskilde Municipality
Illustration 07: Own illustration. Credit: Esben Oxholm.
Illustration 08: Own illustration. Credit: Esben Oxholm.
Illustration 09: Linnebjerg, S. (2016) Winter City Lighting - p. 19. AAU CPH.
Illustration 10: Front pages of the following publications:
Gehl, J. (2010) Cities for People. Edited by J. Gehl. Washington. D.C. : Island Press.
Arup (2015) Rethinking the Shades of Night. London.
Boyce, P. R. (2014) Human Factors in Lighting. 3. ed. Edited by P. R. Boyce. Boca Raton, Fla. : CRC Press.
Brandi, U. and Geissmar-Brandi, C. (2007) Light for Cities. Edited by U. B. Licht. Birkhäuser - Publishers for Architecture. doi: 10.1007/978-3-7643-8263-6.
Casciani, D. and Rossi, M. (2012) 'ELSE , Experience of Lighting Sustainability in the Environment', Cumulus Helsinki Conference, (May 2004), pp. 1–14.
Håndbog Vejbelysning (2015).
Lynch, K. (1960) The image of the city. Edited by K. Lynch. Cambridge Mass. : M.I.T. Press under the auspices of the Joint Center for Urban Studies.
Whyte, W. H. (2001) The social life of small urban spaces / by William H. Whyte. 7. printin. Edited by W. H. Whyte. New York : Project for Public Spaces.
Illustration 11: Gehl, J. (2010) Cities for People - p. 21. Edited by J. Gehl. Washington. D.C. : Island Press.
Illustration 12: Gehl, J. (2010) Cities for People - p. 2. Edited by J. Gehl. Washington. D.C. : Island Press.
Illustration 13: Gehl, J. (2010) Cities for People - p. 53. Edited by J. Gehl. Washington. D.C. :

Island Press.
Illustration 14: Gehl, J. (2010) Cities for People - p. 78. Edited by J. Gehl. Washington. D.C. : Island Press.
Illustration 15: Whyte, W. H. (2001) The social life of small urban spaces - p. 95 / by William H. Whyte. 7. printin. Edited by W. H. Whyte. New York : Project for Public Spaces.
Illustration 16: Arup (2015) Rethinking the Shades of Night - p. 12. London.
Illustration 17: Brandi, U. and Geissmar-Brandi, C. (2007) Light for Cities - p. 77. Edited by U. B. Licht. Birkhäuser - Publishers for Architecture. doi: 10.1007/978-3-7643-8263-6.
I**llustration 18:** Boyce, P. R. (2014) Human Factors in Lighting - p 448. 3. ed. Edited by P. R. Boyce. Boca Raton, Fla. : CRC Press.
Illustration 19: Darksky.org (2013) Light Pollution Diagram [image] Available at: http://darksky.org/light-pollution/ [Accessed: 8 December 2016]
Illustration 20: Håndbog Vejbelysning (2015) p. 20.
Illustration 21: Håndbog Vejbelysning (2015) p. 20.
Illustration 22: Håndbog Vejbelysning (2015) p. 20.
Illustration 23: Håndbog Vejbelysning (2015) p. 20.
Illustration 24: Håndbog Vejbelysning (2015) p. 24.
Illustration 25: Håndbog Vejbelysning (2015) p. 92.
Illustration 26: See Appendix 3 - Award Winning Projects
Illustration 27: Own illustration. Credit: Esben Oxholm.
Illustration 28: Own illustration. Credit: Esben Oxholm.
Illustration 29: Own illustration. Credit: Esben Oxholm.
Illustration 30: Own illustration. Credit: Esben Oxholm.
Illustration 31: Own illustration. Credit: Esben Oxholm.
Illustration 32: Own illustration. Credit: Esben Oxholm.
Illustration 33: Own illustration. Credit: Esben Oxholm.
Illustration 34: Own illustration. Credit: Esben Oxholm.
Illustration 35: Own illustration. Credit: Esben Oxholm. Map data: Google
Illustration 36: Own illustration. Credit: Esben Oxholm.
Illustration 37: Own illustration. Credit: Esben Oxholm.
Illustration 38: Own illustration. Credit: Esben Oxholm.
Illustration 39: Own illustration. Credit: Esben Oxholm. Map data: Google
Illustration 40: Own illustration. Credit: Esben Oxholm. Map data: Google

9 APPENDIX

1 COOPERATION DOCUMENT

Lighting Metropolis

Samarbejdstilkendegivelse om udviklingsprojektet 'Musicon-stien' mellem

Roskilde Kommune
By, Kultur og Miljø
EAN-nummer: 5798007934934
Rådhusbuen 1, 4000 Roskilde
Gunilla Rasmussen
gunillasr@roskilde.dk

Aalborg University Copenhagen
[Lighting Design]
[Indsæt CVR/EAN nummer]
[Indsæt Adresse postnummer]:
Georgios Triantafyllidis
gt@create.aau.dk

DONG Energy
City Light
CVR-nummer: 20214414
Teknikerbyen 25, 2830 Virum
Tine Byskov Søndergaard
tinso@dongenergy.dk

1. Projektets formål og fælles udviklingsmål er at udvikle og realisere Musicon-stien som et demonstrationsprojekt for belysning, der:
   - er innovativt ved at anvende eksisterende teknologier på nye måder
   - er bæredygtigt i forhold til energiforbrug og vedligeholdelse
   - fungerer som Living Lab ved at undersøge interaktioner mellem intelligent belysning og brugernes adfærd

2. Partnernes selvstændige udviklingsmål for Projektet og iværksættelse af kompetencer.

   a. Roskilde Kommune forventer via Projektet at få realiseret belysning på Musicon-stien - fokuseret på 7 krydsningspunkter -, der:
      - tilfører ruten en særlig identitet, som bygger op til ankomsten til Musicon
      - fungerer som pejlemærker og derved tydelig vejvisning, der på en dragende måde leder besøgende ad stien
      - inviterer til ophold og leg undervejs på ruten
      - varsler - med en ændring af belysningen -, når der foregår begivenheder på Musicon/ Dyrskuepladsen og
      - er nemt og relativt billigt at vedligeholde og anvende (energiforbrug) og overholder retningslinjer for belysning på offentlige arealer i forhold til tæthed og hærværk

      Roskilde Kommune forventer desuden at få re-designet/ videreudviklet eksisterende belysning på 3 pladsdannelser på Rabalderstræde, samt at det samlede projekt vil fungere som et interessant Living Lab for professionelle og dermed som potentielt besøgsmål.

      Roskilde Kommune vil bidrage til at opnå dette i kraft af organisationens:
      - erfaring, kompetencer og viden indenfor udvikling og anlæg af byrum og sti- og vejanlæg samt trafikplanlægning

- lokalkendskab, kontakter til områdets brugere samt viden fra forudgående brugerdialog og udviklingsarbejde herunder specifikationer i forhold til behov, ønsker, økonomi og tidsramme
- erfaring og kompetencer indenfor overordnet projektledelse, der vil blive anvendt til at facilitere samarbejdet, lede til konklusioner undervejs i processen og overholde tidsplanen
- erfaring og kompetencer indenfor formidling, der vil blive anvendt til at kommunikere projektet overfor det samlede Lighting Metropolis-samarbejde
- erfaring og kompetencer til at vurdere løsningsforslag i forhold til behov og kontekst, der i projektet vil blive anvendt til at give feedback på studerendes arbejde i hver fase

b. AAU forventer via Projektet at opnå at:
   - undersøge og analysere angående innovation, bæredygtighed, living lab, interaktion, brugernes deltagelse, Roskildes identitet, brugerprofiler, tilgængelig teknologi, økonomi etc.
   - formulere et tema og overordnet design for de 7 nedslagspunkter på Musicon-stien
   - udarbejde specifikke design (f.eks. en prototype, et specifikt design for et af de 7 punkter, specifikke belysnings-scenarier for pladsdannelser på Rabalderstræde eller et fokus på et af aspekterne i design-temaet)
   - få mere teknisk viden om DMX-programmering
   - producere analyser, som kan blive anvendt i design og evaluering
   - evaluere og vurdere forskellige design og formulere problemstillinger
   - designe måder at engagere mennesker til at deltage og interagere socialt
   - udgive og formidle resultaterne af forskningen

   AAU vil bidrage til at opnå dette i kraft af organisationens erfaring, kompetencer og viden indenfor:
   - en forskningsbaseret tilgang og skabelse af ny viden og opdagelser, hvilket i projektet vil blive anvendt til at definere de problemstillinger, Living Lab'et skal undersøge og teste
   - medieteknologi
   - evalueringsmetoder

c. DONG Energy forventer via Projektet at opnå:
   - bredere kendskab og erfaringer med nye muligheder, produkter og løsninger inden for intelligent belysning i 1:1 lysprojekter
   - kendskab og erfaring med etablering af fremtidens intelligente belysning
   - at bidrage til innovation og udvikling af intelligent lys
   - at deltage i og bidrage til konkrete cases på Musicon-stien til egen udvikling og udvikling af produkt/ løsning til fremtidens kundeopgaver.
   - at udgive og formidle resultater af projektet

   DONG Energy vil bidrage til at opnå dette i kraft af organisationens:
   - erfaring, kompetencer og viden indenfor rådgivning i forhold til valg af produkter, projektering, etablering og drift af belysningsanlæg, styring, Smart City m.v.
   - erfaring, kompetencer og viden indenfor projekt- og arbejdsledelse
   - erfaring, kompetencer og viden indenfor installation (Montører, Operatør) og asset management (?)
   - brede og solide netværk af underentreprenører og leverandører.
   - viden om typiske produkter ifht. egenskaber, priser og vedligeholdelse og evne til at vurdere nye produkter på baggrund af tilgængelig data

3. Identificering af parter med nødvendige supplerende kompetencer for at nå projektets fælles udviklingsmål og leverancer:
    1. 2-3 lysdesign-virksomheder (smv'er) til at designe belysning på nogle af/ alle de 7 punkter på stien
    2. Seas NVE, som driftsansvarlig, til at kvalitetssikre design i forhold til tilslutning til overordnet vejbelysning og efterfølgende drift
    3. eventuelt lysdesign-rådgiver til at kvalitetssikre og give AAU-studerende feedback på projektforslag til lysdesign af et eller flere af punkterne på stien (enten smv eller ÅF)
    4. eventuelt virksomheder, der kan udvikle prototyper i lille skala, til testning af idé til applikation/ intelligent belysning før installering

Samarbejdstilkendegivelsen er ikke juridisk bindende, og en part kan derfor træde ud ved begrundet ønske herom.

De nævnte parter tilkendegiver hermed at ville indgå et udbudsfrit OPI-samarbejde i Lighting Metropolis-regi om at skabe udviklingsprojektet 'Musicon-stien', der så vidt muligt

- tager udgangspunkt i borgernes behov og ønsker
- er et triple helix-samarbejde (dvs. et samarbejde mellem kommune/region, virksomhed, universitet)
- er landegrænseoverskridende mellem dansk/svenske aktører
- involverer små og mellemstore virksomheder (SMV'er) og/eller startups
- skaber nye metoder, løsninger og produkter
- er innovativt
- skaber arbejdspladser.

Samarbejdstilkendegivelsens parter:

Roskilde Kommune
Gunilla Rasmussen

_____
[Skriv Dato, Underskrift]

Aalborg University Copenhagen
Georgios Triantafyllidis

_____
[Skriv Dato, Underskrift]

DONG Energy
Tine Byskov Søndergaard

_____
[Skriv Dato, Underskrift]

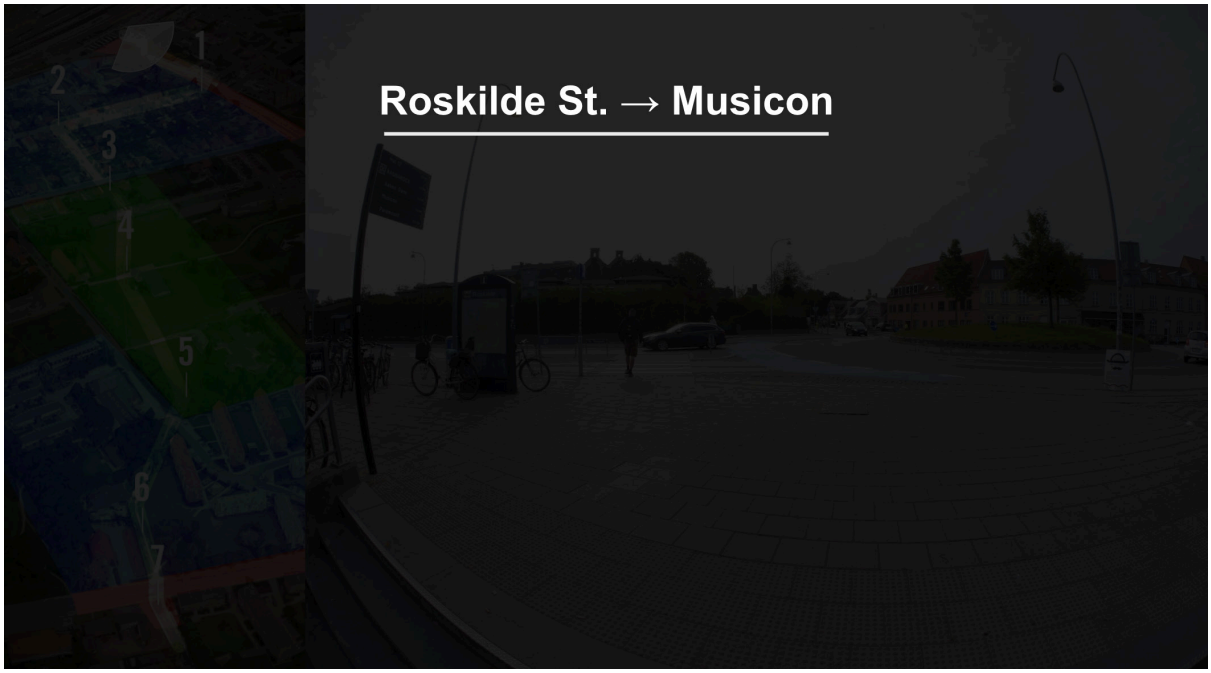
Følgende punkter indgår i udarbejdelsen af en udbudsfri OPI-aftale og ikke i nærværende samarbejdstilkendegivelse

1. Projektøkonomi: Lav Budget for projektet, der omfatter økonomiske og mandskabsmæssige ressourcer fra partnerne.

2. Tidsramme for projektet
3. Tidsplan for Projektet
4. Risici for Partnere og Projektet

Relevante referencer i forbindelse med udarbejdelse af en udbudsfri OPI-aftale:
http://www.plan-c.dk/Modeller-og-vaerktoejer/Udbudsfri-OPI/

2 SPATIAL FLOW

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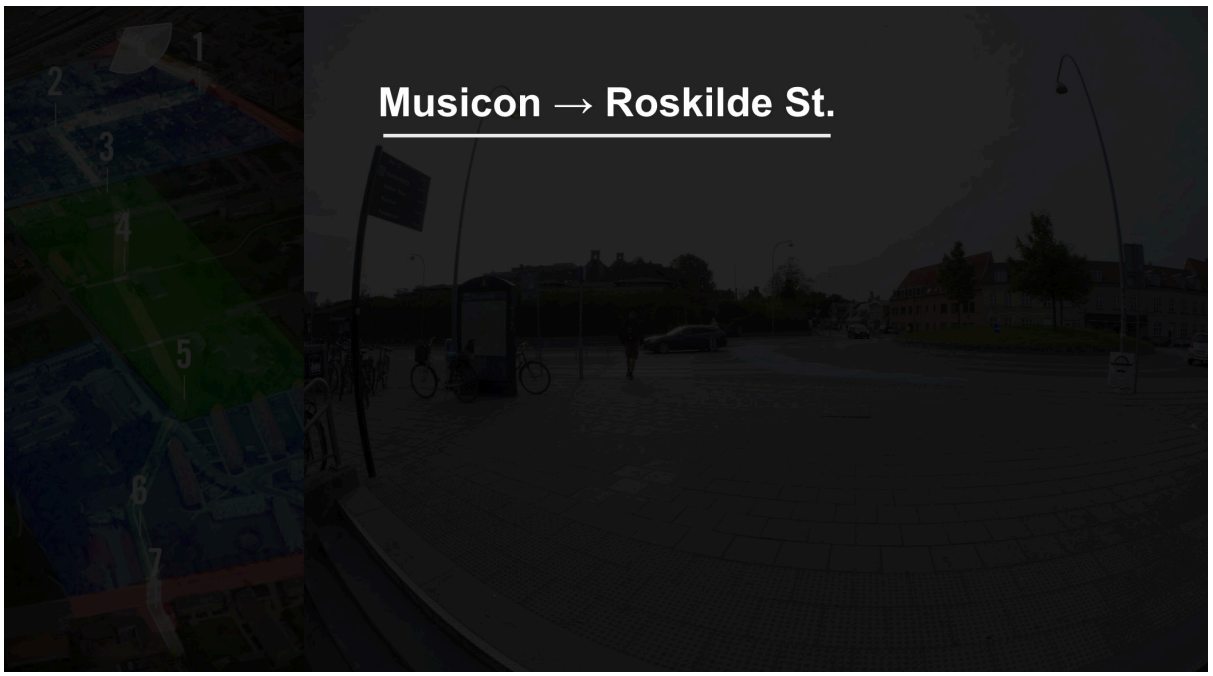
Musicon → Roskilde St.


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3 AWARD WINNING PROJECTS

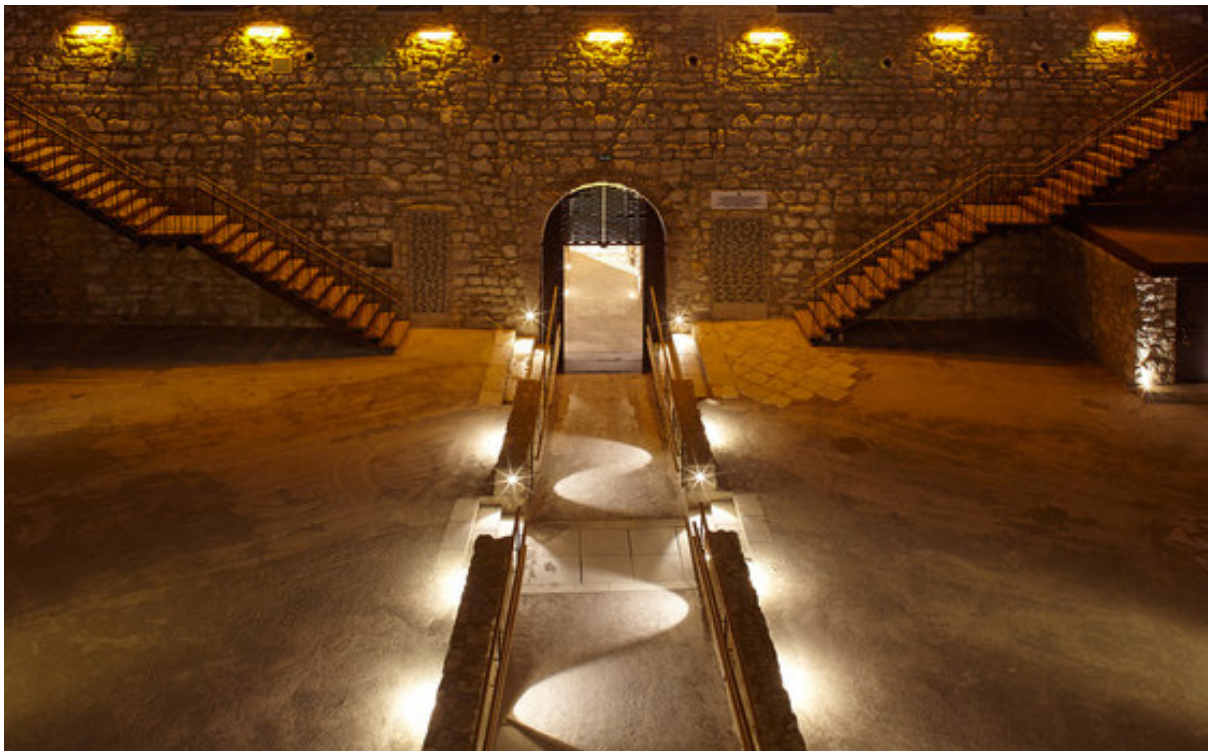
To uncover potentials for lighting designs, not mentioned in the investigated literature, a qualitative review of recent lighting design award winners has been conducted.

The projects presented below have been awarded in either LUCI/PHILIPS' city.people.light, IALD or Den Danske Lyspris and is related to urban lighting.

The LUCI/PHILIPS' city.people.light is an award that highlights that shows the best ways that lighting can add value in the urban environment. The award is based on a collaboration of PHILIPS and LUCI, Lighting Urban Community International, an international network that brings together cities and lighting designers who works to use lighting for sustainable, social and economic development.

IALD, the International Association of Lighting Designers, is a worldwide organization for independent lighting designers. Once a year the honor innovative and inspiring architectural lighting design projects from around the world.

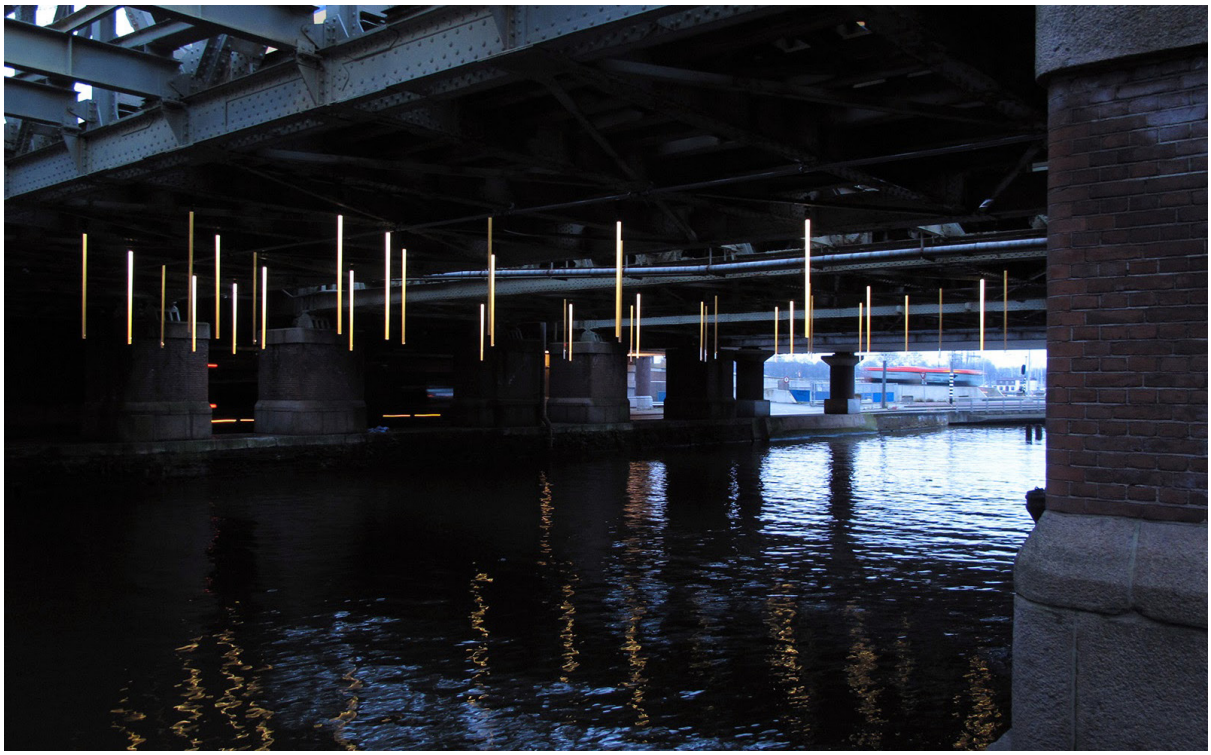
Dansk Center for Lys (Danish Center for Lighting) is behind Den Danske Lyspris (The Danish Lighting Award). It awards Danish lighting design projects that excels in creating good lighting with a human centered approach.



VICTORIA GRANDE FORTRESS, MELILLA, SPAIN
City.people.light 2015 - People Choice Award

The lighting design of the Victoria Grande Fortress was awarded with the People Choice Award for several reasons. First of all the integration of high quality linear LED luminaires in the architecture is mentioned. The luminaries are carefully positioned in places where they are not visible while providing the needed light. Furthermore, the subtle way of using different color temperatures to emphasize specific details is mentioned. As a last thing, the lighting design also uses a battery-driven candlelight-like LED luminaire that is controllable together with the rest of the luminaires through a ZigBee protocol.

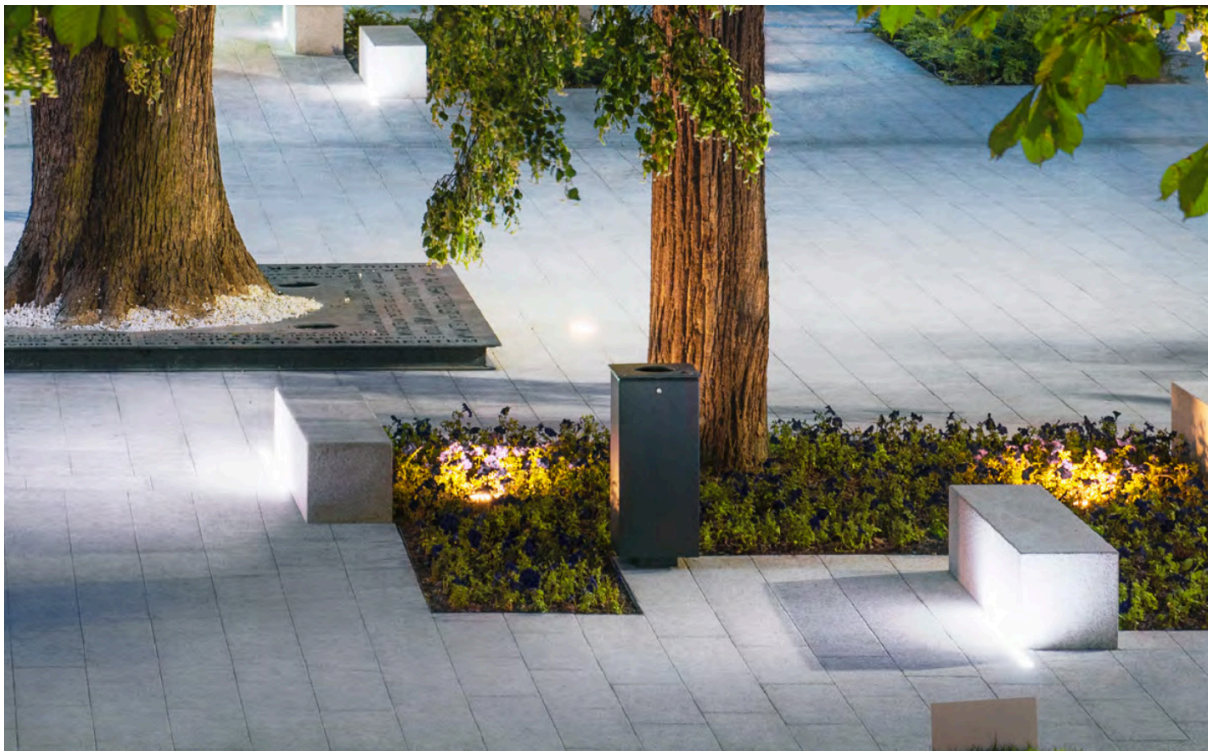
https://www.architonic.com/en/project/linea-light-group-reference-projects-victoria-grande-fortress/5102690 (Accessed: 12 December 2016)



HANG IN THERE, AMSTERDAM, THE NETHERLANDS
City.people.light 2015 - Special Mention

‘Hang in there’ is a quite simple, yet effective installation under a railway bridge in the city of Amsterdam. It consists of 36 beams of light hanging from the ceiling of the bridge. The lighting from the beams fades slowly and randomly, thus creating a sense of life and making the underpass a more attractive route to travel.

http://jasperklinkhamer.nl/hang-in-there-you-will-be-fine/ (Accessed: 12 December 2016)



REHABILITATION OF FORTRESS SQUARE, BAIA MARE, ROMANIA
City.people.light 2015 - 3rd prize

The lighting of Fortress Square is mentioned for its general ambient atmosphere and concurrent highlighting of buildings, trees and circulation areas. The lighting is coming from integrated LED sources and from spots positioned on poles. Difference in color temperature has been used to separate the borders and the center of the square.

http://www.philips.com/content/dam/corporate/homepage-articles/ro/case_study_baia_mare_Romania.pdf (Accessed: 12 December 2016)

ARTISTIC ESCAPES AT TWILIGHT, LIGHTING MASTERPLAN, VALENCIENNES, FRANCE
City.people.light 2015 - 2nd prize

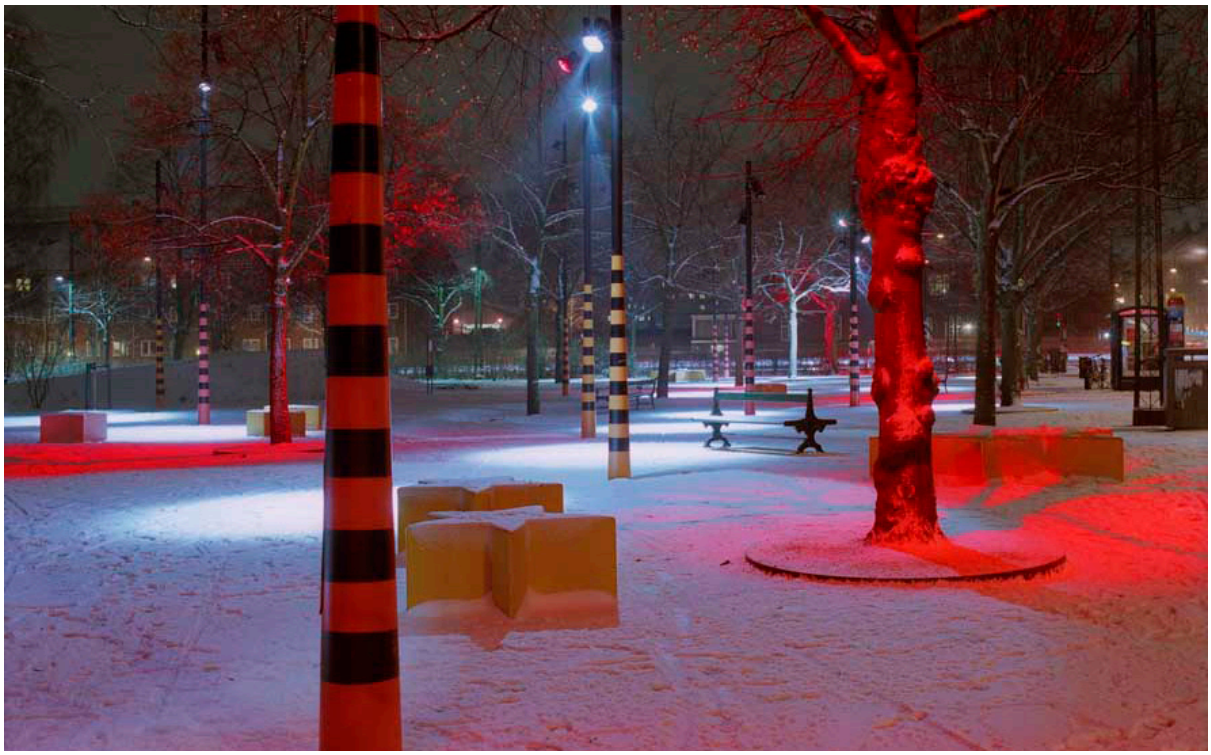
The masterplan of Valenciennes in France won the second prize in the city.people.light 2015 due to its contextual considerations and interactive solution. At routes through sensitive zones, presence detectors detect when people are using the path and turns on a bright lighting with good color rendition qualities. When nobody is around the lighting is reduced to a subtle warm white low intensity glow with low impact on the flora and fauna. The entrances of the path, which are away from sensitive zones, is marked with bright projections to make the bypassers aware of the path.

http://www.concepto.fr/portfolio_page/rhonelle-park-valenciennes-france-3/ (Accessed: 12 December 2016)

NEW NIGHTSCAPE LIGHTING MASTERPLAN, AVILA, SPAIN
City.people.light 2015 - 1st prize

The lighting masterplan of Avila in Spain upgraded all existing street lighting. It won for its layered approach to lighting combining functional and ornamental purposes. Also the architectural adaptation and integration of the light sources is highlighted as a well done feature.

http://www.aureolighting.com/project/proyecto-avila/ (Accessed: 12 December 2016)



NORDVEST PARKEN, COPENHAGEN, DENMARK
The Danish Light Award 2010

The lighting design for Nordvest Parken in Copenhagen, won the Danish Light Award in 2010 for its unconventional and alternative solutions. The overall “theme” is based on the milky way and colorful lighting. It is mentioned that the playful and “freaky” lighting fits well with the context of all the different inhabitants using the park. A well done feature is the lighting of trees from above, minimizing vandalism and light pollution. Although Nordvest Parken won, a few remarks are given: Some areas along the path is insufficient lit and other areas are subject to glary light sources, compromising comfort and the sense of safety.

http://www.centerforlys.dk/nyheder_fuld.php?id=347 (Accessed: 12 December 2016)
http://www.e-architect.co.uk/images/jpgs/copenhagen/nord_vest_park_s240111_tp6.jpg (Accessed: 12 December 2016)

SAINT GERVAIS DISTRICT, GENÉVE, SWITZERLAND
City.people.light 2013 - 3rd prize

In Genéve, Switzerland the lighting design for the St-Gervais-district, containing the plazas Simon-Goulart, Saint-Gervais og Bel-Air, was awarded with the third place in the city.people. light 2013. The reason for winning was partly because of a seamless integration of the light sources and an interactive layering. The luminaires are either suspended in wires eight meters above the plazas, hanging in poles or are wall mounted, leaving space for urban furniture, paths, etc. As Place de Bel-Air is known as a windy place, the lighting changes color depending on the wind speed. This serves as a talking point for the locals and helps to give the plaza an identity on its own.

http://www.lighting.philips.com/main/cases/cases/parks-and-plazas/saint-gervais-district.html (Accessed: 12 December 2016)

INTERACTIVE LIGHTING PREVENTING CRIME THROUGH ENVIRONMENTAL DESIGN, WELLINGTON, NEW ZEALAND
City.people.light 2014 - Special Mention

In Wellington in New Zealand, a narrow dark street has by the use of an interactive lighting scheme been transformed into a safe and fun path to traverse. Presence detectors triggers playful lighting schemes emitted from carefully positioned sources preventing glare and spilled light, enhancing the sensation of a safe and lively place.

http://www.philips.com/a-w/about/news/archive/standard/newsbackgrounders/2014/20141110-media-backgrounder-citypeoplelight-2014.html (Accessed: 12 December 2016)

RICHARD-WAGNER-PLATZ, LEIPZIG, GERMANY
City.People.Light 2014 - 1st prize

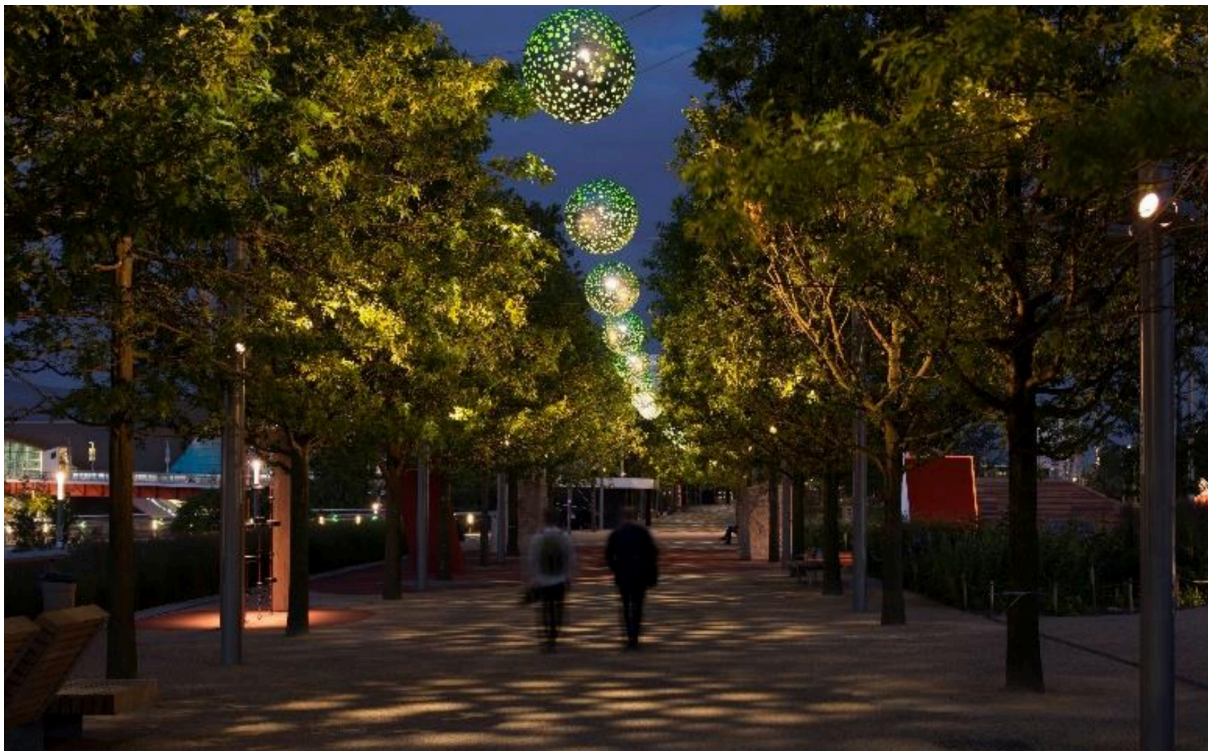
Not much is said about the winner of the city.people.light award winner 2014. The lighting design of Richard-Wagner-Platz in the city of Leipzig, is mentioned for its thoughtful use and integration of contemporary LED lighting to preserve and highlight historic elements, while keeping the energy levels at a minimum.

http://www.philips.com/a-w/about/news/archive/standard/newsbackgrounders/2014/20141110-media-backgrounder-citypeoplelight-2014.html (Accessed: 12 December 2016)

BICYCLE SNAKE BRIDGE, COPENHAGEN, DENMARK
City.People.Light 2014 - 1st prize

The lighting in the sculptural bicycle snake bridge in Copenhagen is mentioned for it seamless integration and soft light coming from the railing at the edges of the bridge. By placing the LED sources here, the surface of the bridge is lit up, while preventing glare and direct light pollution.

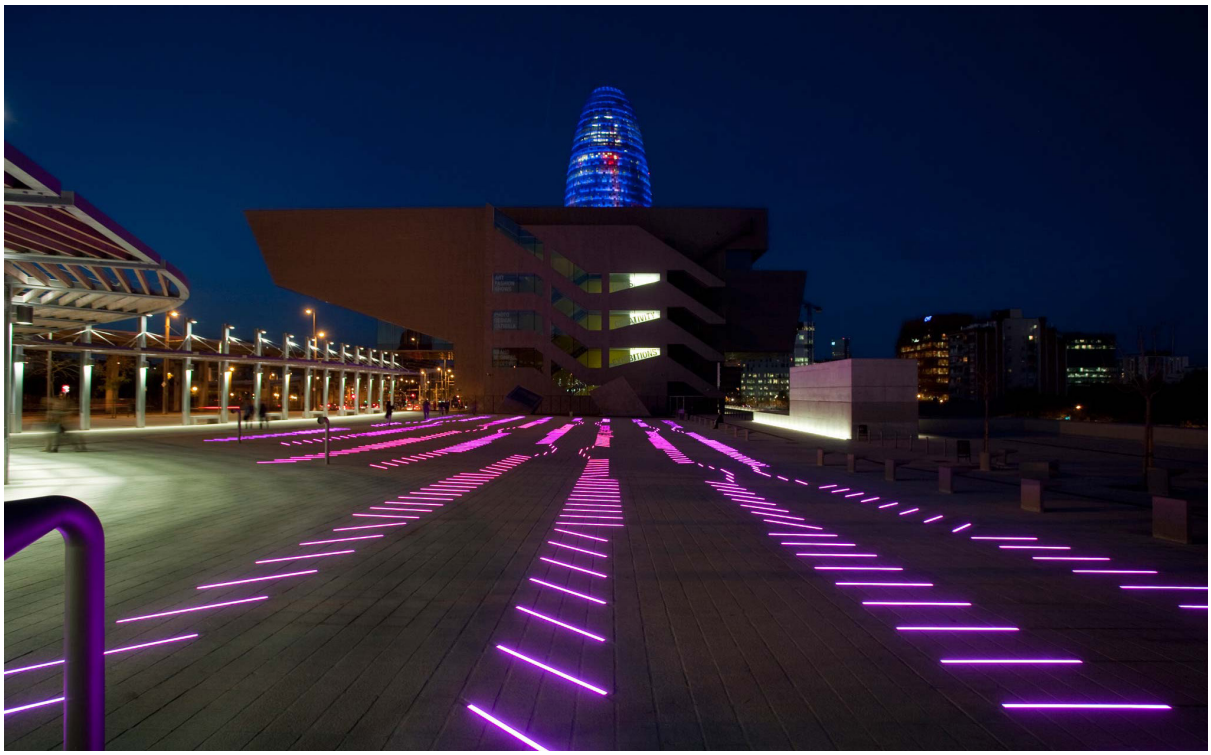
http://www.philips.com/a-w/about/news/archive/standard/newsbackgrounders/2014/20141110-media-backgrounder-citypeoplelight-2014.html (Accessed: 12 December 2016)



QUEEN ELIZABETH PARK, LONDON, UK
IALD Award 2015 of Merit

The challenges for the lighting in Queen Elizabeth Olympic Park in London was to provide a safe and secure feeling while supporting the joyful features of the park design. The solution is created as a long row of light emitting spherical elements centered above a path, framed by lit tree canopies along each side. The lighting design takes a layered approach and utilizes the flexible features of modern LED sources. The spherical elements provide a guidance and lights up the otherwise flat and grey path in an interesting way.

https://www.iald.org/IALD/media/Media-Library/IALD%20International%20Lighting%20Design%20Awards/2015/MERIT-Queen-Elizabeth-Park.pdf (Accessed: 12 December 2016)



BRUUMRUUM! BARCELONA, SPAIN

IALD 2014 - Special citation for an intuitive, interactive lighting experience

BruumRuum! is an interactive lighting installation at Plaça de les Glories in Barcelona, Spain. The installation consists of 550 linear luminaires integrated in the ground. Sound sensitive sensors are installed around the plaza enabling the lighting to react on the voice of people and ambient sounds from the surrounding city.

http://www.ledsmagazine.com/ugc/2014/09/02/bruumruum-interactive-outdoor-lighitng-project-in-spain-gains-insta-s-led-technology-an-iald-award.html (Accessed: 12 December 2016)

http://ledscontrol.com/wp-content/uploads/2015/11/BruumRuum0-1.jpg (Accessed: 12 December 2016)

WALL ILLUMINATION FANTASY OF PIOLE HIMEJI HYOGO, JAPAN

IALD 2014 - Special citation for the elegant integration of indirect dynamic lighting

The Wall Illumination Fantasy of Piole Himeji Hyogo in Japan is mentioned for its integration of indirect dynamic lighting on the facade of Piole Himeji. The facade consists of protruding and retracted rectangular elements, each equipped with full color LEDs along the circumference. The lighting is animated to resemble human figures, sunshine through foliage and the stone wall of the Himeji Castle.

http://ialdawards2014.conferencespot.org/awards-at-a-glance/016-wall-illumination-fantasy-of-piole-himeji-1.1128835 (Accessed: 12 December 2016)

4 DATA REGISTRATIONS

SCENARIO 1											
enter frame	**exit frame**	**frames**	**time**	**m/s**	**km/h**						
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65898	66060	162	6.48	1.40	5.06						
67868	68077	209	8.36	1.09	3.92						
69065	69218	153	6.12	1.49	5.35						
70505	70692	187	7.48	1.22	4.38						
70684	70849	165	6.6	1.38	4.96						
74534	74720	186	7.44	1.22	4.40						
75079	75218	139	5.56	1.64	5.89						
77828	77971	143	5.72	1.59	5.73						
78155	78282	127	5.08	1.79	6.45						
78600	78776	176	7.04	1.29	4.65						
78616	78776	160	6.4	1.42	5.12						
78687	78840	153	6.12	1.49	5.35						
79061	79179	118	4.72	1.93	6.94						
84172	84352	180	7.2	1.26	4.55						
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105668	105829	161	6.44	1.41	5.09						
108084	108250	166	6.64	1.37	4.93						
111337	111492	155	6.2	1.47	5.28						
112999	113139	140	5.6	1.63	5.85						
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127319	127469	150	6	1.52	5.46						
127319	127469	150	6	1.52	5.46						
128144	128305	161	6.44	1.41	5.09						
130439	130570	131	5.24	1.74	6.25						
130445	130570	125	5	1.82	6.55						
133141	133274	133	5.32	1.71	6.16						
133534	133680	146	5.84	1.56	5.61						
133534	133687	153	6.12	1.49	5.35						
134121	134305	184	7.36	1.24	4.45						
				AVG speed	**5.28**	**km/h**					
SCENARIO 2			*Before lights*				*Alongside lights*				
enter frame	**mid frame**	**exit frame**	**frames**	**time**	**m/s**	**km/h**	**frames**	**time**	**m/s**	**km/h**	
419	572	725	153	6.12	1.49	5.35	153	6.12	1.49	5.35	

3973	4117	4270	144	5.76	1.58	5.69	153	6.12	1.49	5.35	
6323	6458	6600	135	5.4	1.69	6.07	142	5.68	1.60	5.77	
7641	7796	7954	155	6.2	1.47	5.28	158	6.32	1.44	5.18	
8428	8590	8742	162	6.48	1.40	5.06	152	6.08	1.50	5.39	
12485	12679	12866	194	7.76	1.17	4.22	187	7.48	1.22	4.38	
12485	12679	12866	194	7.76	1.17	4.22	187	7.48	1.22	4.38	
13977	14163	14380	186	7.44	1.22	4.40	221	8.84	1.03	3.71	
13977	14184	14384	207	8.28	1.10	3.96	200	8	1.14	4.10	
14978	15114	15263	136	5.44	1.67	6.02	149	5.96	1.53	5.50	
15262	15453	15636	191	7.64	1.19	4.29	183	7.32	1.24	4.48	
18388	18580	18760	192	7.68	1.18	4.27	180	7.2	1.26	4.55	
18827	18996	19165	169	6.76	1.35	4.85	169	6.76	1.35	4.85	
18827	18996	19165	169	6.76	1.35	4.85	169	6.76	1.35	4.85	
25744	25914	26077	170	6.8	1.34	4.82	163	6.52	1.40	5.02	
25744	25918	26077	174	6.96	1.31	4.71	159	6.36	1.43	5.15	
36114	36285	36448	171	6.84	1.33	4.79	163	6.52	1.40	5.02	
37511	37653	37793	142	5.68	1.60	5.77	140	5.6	1.63	5.85	
37565	37743	37909	178	7.12	1.28	4.60	166	6.64	1.37	4.93	
40143	40313	40477	170	6.8	1.34	4.82	164	6.56	1.39	4.99	
43359	43526	43683	167	6.68	1.36	4.90	157	6.28	1.45	5.22	
45481	45646	45810	165	6.6	1.38	4.96	164	6.56	1.39	4.99	
45481	45646	45810	165	6.6	1.38	4.96	1838	73.52	0.12	0.45	
47170	47333	47484	163	6.52	1.40	5.02	151	6.04	1.51	5.42	
48663	48809	48957	146	5.84	1.56	5.61	148	5.92	1.54	5.53	
50908	51050	51189	142	5.68	1.60	5.77	139	5.56	1.64	5.89	
52021	52197	52369	176	7.04	1.29	4.65	172	6.88	1.32	4.76	
60166	60344	60549	178	7.12	1.28	4.60	205	8.2	1.11	4.00	
60166	60344	60549	178	7.12	1.28	4.60	205	8.2	1.11	4.00	
61228	61403	61572	175	7	1.30	4.68	169	6.76	1.35	4.85	
61228	61410	61582	182	7.28	1.25	4.50	172	6.88	1.32	4.76	
61461	61604	61742	143	5.72	1.59	5.73	138	5.52	1.65	5.93	
64554	64738	64913	184	7.36	1.24	4.45	175	7	1.30	4.68	
66658	66828	66984	170	6.8	1.34	4.82	156	6.24	1.46	5.25	
69103	69290	69495	187	7.48	1.22	4.38	205	8.2	1.11	4.00	
73629	73758	73891	129	5.16	1.76	6.35	133	5.32	1.71	6.16	
					AVG speed	**4.94**	**km/h**		**AVG speed**	**4.85**	**km/h**
SCENARIO 3			*Before lights*				*Alongside lights*				
enter frame	**mid frame**	**exit frame**	**frames**	**time**	**m/s**	**km/h**	**frames**	**time**	**m/s**	**km/h**	
575	771	945	196	7.84	1.16	4.18	174	6.96	1.31	4.71	
5718	5855	6004	137	5.48	1.66	5.98	149	5.96	1.53	5.50	
7358	7518	7671	160	6.4	1.42	5.12	153	6.12	1.49	5.35	
8617	8765	8909	148	5.92	1.54	5.53	144	5.76	1.58	5.69	
9359	9516	9662	157	6.28	1.45	5.22	146	5.84	1.56	5.61	
9370	9521	9656	151	6.04	1.51	5.42	135	5.4	1.69	6.07	
16690	16857	17018	167	6.68	1.36	4.90	161	6.44	1.41	5.09	
18088	18266	18435	178	7.12	1.28	4.60	169	6.76	1.35	4.85	
19431	19582	19719	151	6.04	1.51	5.42	137	5.48	1.66	5.98	
21038	21187	21328	149	5.96	1.53	5.50	141	5.64	1.61	5.81	
21970	22143	22330	173	6.92	1.32	4.73	187	7.48	1.22	4.38	
21970	22143	22330	173	6.92	1.32	4.73	187	7.48	1.22	4.38	
22117	22257	22393	140	5.6	1.63	5.85	136	5.44	1.67	6.02	
23132	23297	23453	165	6.6	1.38	4.96	156	6.24	1.46	5.25	

23132	23297	23453	165	6.6	1.38	4.96	156	6.24	1.46	5.25	
25650	25810	25963	160	6.4	1.42	5.12	153	6.12	1.49	5.35	
25727	25914	26066	187	7.48	1.22	4.38	152	6.08	1.50	5.39	
25735	25914	26071	179	7.16	1.27	4.58	157	6.28	1.45	5.22	
27838	28013	28165	175	7	1.30	4.68	152	6.08	1.50	5.39	
27850	28013	28165	163	6.52	1.40	5.02	152	6.08	1.50	5.39	
28277	28431	28579	154	6.16	1.48	5.32	148	5.92	1.54	5.53	
30437	30608	30773	171	6.84	1.33	4.79	165	6.6	1.38	4.96	
30491	30653	30809	162	6.48	1.40	5.06	156	6.24	1.46	5.25	
31567	31725	31881	158	6.32	1.44	5.18	156	6.24	1.46	5.25	
37481	37648	37807	167	6.68	1.36	4.90	159	6.36	1.43	5.15	
37481	37648	37807	167	6.68	1.36	4.90	159	6.36	1.43	5.15	
37497	37668	37828	171	6.84	1.33	4.79	160	6.4	1.42	5.12	
37497	37668	37828	171	6.84	1.33	4.79	160	6.4	1.42	5.12	
38424	38566	38705	142	5.68	1.60	5.77	139	5.56	1.64	5.89	
39644	39772	39897	128	5.12	1.78	6.40	125	5	1.82	6.55	
40242	40383	40519	141	5.64	1.61	5.81	136	5.44	1.67	6.02	
40678	40838	40984	160	6.4	1.42	5.12	146	5.84	1.56	5.61	
41347	41497	41637	150	6	1.52	5.46	140	5.6	1.63	5.85	
47386	47522	47650	136	5.44	1.67	6.02	128	5.12	1.78	6.40	
47426	47581	47727	155	6.2	1.47	5.28	146	5.84	1.56	5.61	
51016	51165	51315	149	5.96	1.53	5.50	150	6	1.52	5.46	
51452	51620	51774	168	6.72	1.35	4.88	154	6.16	1.48	5.32	
52959	53097	53232	138	5.52	1.65	5.93	135	5.4	1.69	6.07	
54905	55065	55214	160	6.4	1.42	5.12	149	5.96	1.53	5.50	
55709	55867	56009	158	6.32	1.44	5.18	142	5.68	1.60	5.77	
63496	63648	63784	152	6.08	1.50	5.39	136	5.44	1.67	6.02	
72619	72750	72880	131	5.24	1.74	6.25	130	5.2	1.75	6.30	
75291	75447	75594	156	6.24	1.46	5.25	147	5.88	1.55	5.57	
75781	75957	76126	176	7.04	1.29	4.65	169	6.76	1.35	4.85	
76437	76584	76726	147	5.88	1.55	5.57	142	5.68	1.60	5.77	
					AVG speed	**5.20**	**km/h**		**AVG speed**	**5.48**	**km/h**
SCENARIO 4			*Before lights*				*Alongside lights*				
enter frame	**mid frame**	**exit frame**	**frames**	**time**	**m/s**	**km/h**	**frames**	**time**	**m/s**	**km/h**	
8949	9101	9247	152	6.08	1.50	5.39	146	5.84	1.56	5.61	
10102	10247	10385	145	5.8	1.57	5.65	138	5.52	1.65	5.93	
10712	10878	11041	166	6.64	1.37	4.93	163	6.52	1.40	5.02	
13926	14078	14224	152	6.08	1.50	5.39	146	5.84	1.56	5.61	
14465	14638	14808	173	6.92	1.32	4.73	170	6.8	1.34	4.82	
14465	14638	14808	173	6.92	1.32	4.73	170	6.8	1.34	4.82	
15789	15962	16133	173	6.92	1.32	4.73	171	6.84	1.33	4.79	
16912	17073	17231	161	6.44	1.41	5.09	158	6.32	1.44	5.18	
17157	17310	17467	153	6.12	1.49	5.35	157	6.28	1.45	5.22	
17554	17717	17875	163	6.52	1.40	5.02	158	6.32	1.44	5.18	
17554	17724	17890	170	6.8	1.34	4.82	166	6.64	1.37	4.93	
20114	20322	20512	208	8.32	1.09	3.94	190	7.6	1.20	4.31	
20114	20322	20526	208	8.32	1.09	3.94	204	8.16	1.12	4.01	
20322	20476	20617	154	6.16	1.48	5.32	141	5.64	1.61	5.81	
21680	21822	21965	142	5.68	1.60	5.77	143	5.72	1.59	5.73	
22191	22348	22499	157	6.28	1.45	5.22	151	6.04	1.51	5.42	
24129	24309	24480	180	7.2	1.26	4.55	171	6.84	1.33	4.79	
26329	26548	26747	219	8.76	1.04	3.74	199	7.96	1.14	4.12	

33893	34035	34201	142	5.68	1.60	5.77	166	6.64	1.37	4.93	
33910	34055	34233	145	5.8	1.57	5.65	178	7.12	1.28	4.60	
33910	34064	34233	154	6.16	1.48	5.32	169	6.76	1.35	4.85	
37329	37474	37616	145	5.8	1.57	5.65	142	5.68	1.60	5.77	
37451	37620	37797	169	6.76	1.35	4.85	177	7.08	1.29	4.63	
37977	38128	38279	151	6.04	1.51	5.42	151	6.04	1.51	5.42	
37977	38128	38279	151	6.04	1.51	5.42	151	6.04	1.51	5.42	
37977	38163	38345	186	7.44	1.22	4.40	182	7.28	1.25	4.50	
39986	40157	40321	171	6.84	1.33	4.79	164	6.56	1.39	4.99	
42353	42518	42672	165	6.6	1.38	4.96	154	6.16	1.48	5.32	
42604	42794	42969	190	7.6	1.20	4.31	175	7	1.30	4.68	
42940	43109	43273	169	6.76	1.35	4.85	164	6.56	1.39	4.99	
50526	50657	50787	131	5.24	1.74	6.25	130	5.2	1.75	6.30	
52664	52803	52933	139	5.56	1.64	5.89	130	5.2	1.75	6.30	
52832	52978	53114	146	5.84	1.56	5.61	136	5.44	1.67	6.02	
57583	57723	57869	140	5.6	1.63	5.85	146	5.84	1.56	5.61	
59883	60064	60233	181	7.24	1.26	4.52	169	6.76	1.35	4.85	
59894	60050	60209	156	6.24	1.46	5.25	159	6.36	1.43	5.15	
60367	60527	60675	160	6.4	1.42	5.12	148	5.92	1.54	5.53	
62245	62392	62534	147	5.88	1.55	5.57	142	5.68	1.60	5.77	
64088	64223	64362	135	5.4	1.69	6.07	139	5.56	1.64	5.89	
72178	72353	72509	175	7	1.30	4.68	156	6.24	1.46	5.25	
72194	72353	72509	159	6.36	1.43	5.15	156	6.24	1.46	5.25	
72413	72552	72714	139	5.56	1.64	5.89	162	6.48	1.40	5.06	
76219	76397	76592	178	7.12	1.28	4.60	195	7.8	1.17	4.20	
76219	76408	76601	189	7.56	1.20	4.33	193	7.72	1.18	4.24	
78035	78199	78360	164	6.56	1.39	4.99	161	6.44	1.41	5.09	
79841	80025	80193	184	7.36	1.24	4.45	168	6.72	1.35	4.88	
84483	84620	84751	137	5.48	1.66	5.98	131	5.24	1.74	6.25	
87255	87431	87603	176	7.04	1.29	4.65	172	6.88	1.32	4.76	
89585	89756	89931	171	6.84	1.33	4.79	175	7	1.30	4.68	
94007	94170	94335	163	6.52	1.40	5.02	165	6.6	1.38	4.96	
96960	97118	97270	158	6.32	1.44	5.18	152	6.08	1.50	5.39	
100159	100315	100472	156	6.24	1.46	5.25	157	6.28	1.45	5.22	
100682	100854	101020	172	6.88	1.32	4.76	166	6.64	1.37	4.93	
108404	108568	108731	164	6.56	1.39	4.99	163	6.52	1.40	5.02	
					AVG speed	**5.08**	**km/h**		**AVG speed**	**5.15**	**km/h**