“Urban Space Recreation for Pedestrians through Smart Lighting Control Systems”

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“There has been light from the beginning. There will be light, feebly, at the end. In all its forms, it saturates the universe.

Light is one of life’s necessities. We would not be on this planet if there was no light. When there is no natural light, we need artificial. When early humans first started using fire, they were trying to find many uses for it.”
I would first like to thank my thesis advisor Henrik Gidlund for his guidance while allowing this thesis to be my own work, but steered me in the right direction whenever he thought I needed it.

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ABSTRACT

Connected public lighting for more sustainable and liveable cities is highly demanding research in lighting design field through human centred design approach. While following this understanding, this thesis aims to answer the question “How a networked public lighting can be created in order to enhance the needs of the pedestrians in Fredhällspark?”.

To investigate this study, a background research was studied in the relevant topics of urban lighting, followed by the study of human safety regarding to this topic and lastly the possible new lighting technologies. The main study is involved in a pedestrian path at Fredhällspark in Stockholm, Sweden, in two months duration in the spring time of 2018 by conducting user surveys and taking the lighting measurements.

Based on the results the study showed, a lighting design proposal is developed with a site-specific approach in order to make it up-to-date and sustainable for future urban environments while complying with the requirements of the users.

KEYWORDS

# CONTENT

1. Introduction 4
2. Background Research 5
   2.1. Urban Lighting 5
   2.2. Human Safety and Light 7
   2.3. The Integration of New Lighting Technology 9
3. Methodology 11
   3.1 Observations 11
      3.1.1 Site Analysis 11
         3.1.1.1 Location 11
         3.1.1.2 Surroundings 11
         3.1.1.3 Users 12
         3.1.1.4 Peak Hours 13
         3.1.1.5 Movement 13
      3.1.2 Lighting Analysis 14
   3.2 Qualitative Approach 14
   3.3 Quantitative Approach 14
4. Results 17
5. Conceptual Design 21
   5.1 Design Development 21
   5.2 Design Proposal 24
6. Discussion 25
7. Conclusion & Limitations 26
Bibliography 27
List of Figures 28
List of Tables 31
Appendix A 32
Appendix B 33
Appendix C 34
Appendix D 36
1. Introduction

Urban lighting is the vital part of the cities’ infrastructure especially for more liveable cities regarding the social engagement requirements from human aspect. Due to rapidly increasing demand and need of creating more sustainable and liveable cities, the lighting solutions for urban environments are insufficient and inconvenient in terms of the adaptability of the new technologies and reaching the requirements of the pedestrians. Connected public lighting could be a solution to provide the right amount of light precisely by ensuring when and where it is needed in order to save energy, reduce the obtrusive light while making the urban spaces safer and more attractive (1).

The aim of this study is to investigate how a networked public lighting can be created to enhance the energy savings and social engagements of a certain urban environment, at Fredhällspark in Stockholm, Sweden for pedestrians. Due to complexity of urban lighting infrastructure, there is a certain emergency for interconnection of the new control systems along with the requirements of the human based approach and sustainability. This situation addresses the importance of the analysis for a recreation of an urban space while complying with the requirements of the users, especially in the Scandinavian countries, while they are facing with the long darkness hours in winter times.
2. Background Research

2.1. Urban Lighting

The most significant change in urban lighting started with the usage of electric light in the late 19th century in London. This brought the new understanding of daily life with extension of human activity time by giving the possibility of living in the night life, which was perceiving “dark and dangerous” at that time. Obviously, it also had an influence on the cultural and social structure of the societies, which we have been used to see the visible light at night time without questioning its influences and future in terms of environmental and social aspects. It is a well-known fact that it was because that the pedestrian light was primarily perceived just for safety, danger and recognition of other pedestrians as soon as possible, additionally by providing the orientation to the pedestrians. Since the main focus was to provide ‘safe night time for urban spaces’ for citizens, regrettably for many years the public lighting couldn’t go further than adding new lighting fixtures to the existing ones, while making the cities more visible despite the impossibility of seeing the real darkness in sky (2). However, this current situation of public lighting comes from the complexity of the technological implementations to the urban spaces specifically and adaptively. This brings to us the emergency of finding new solutions for urban lighting to integrate the new lighting systems to the urban environments. Improvement will not be possible if the urban lighting is not designed with a specific attention. Urban lighting can change the existing impact of the urban typology and give a revitalization to the urban life and the urban image (3). Light should be offered to the urban dweller and invite him / her ‘to be in city’ (4). The new lighting understanding shouldn’t be just based on brightness, it must be an adaptation of the urban spaces into the changing times and the seasons by aiming to also integrate the citizens to the urban space while ensuring the appreciation of the urban space. Although the urban lighting is divided into two different categories, as street and pedestrian lighting, this is not exactly right thing to do. The aim has to be to create a continuous transition of the light effect while making the main concern the nuances of the light. This understanding shows that the lighting for local environments and mainly for pedestrians should be possible for different schemes or situations without disrupting the general appearance or the image of the cities. Obviously, urban lighting composed of different parts and elements with people from different disciplines, so it is a huge system including the city authorities, workers, citizens from many different perspectives. Nowadays it is a very clear question is that ‘Where is the public space that should be lit and what space should be available at night as well (5). Although the urban lighting design requires basic principles, for differentiation and adaptation it is a need that the lighting solutions based on site and technically adaptable approaches will distinguish the environments and create more vibrant urban images while decreasing the operation and maintenance costs.
For more deep understanding, urban lighting can be discussed through on basic lighting principles.

1. **Illuminance**

   It describes the amount of light illuminates the surface. For pedestrians, it can be divided into two categories; horizontal and vertical illuminance. While horizontal illuminance aims to give the safety movement, the vertical illuminance aims to give the visibility to recognize the surroundings (6).

2. **Luminance**

   It describes the amount of light which is reflected from the surface, by falling within a given solid angle. Human eye can perceive the luminance as a reflected light amount dependent on the material, colours, textures and etc. This addresses different visual impressions on the people, which can change the space and size perception (7).

3. **Contrast**

   Contrast is the difference in luminance or colour which makes an object distinguishable for human eye. It has huge impact on to recognize and identify the surroundings with instant eye adaptation. Having high contrast can create a glare problem, which makes the people not able to see around instantly. In urban context, although high contrast could be dangerous, the background contrast is an important criteria for surroundings (8).

4. **Light Distribution**

   The light distribution can be very crucial to identify the space and surrounding people. A pedestrian should be able to see the approaching person’s feet, legs, body and face although the main purpose is to provide a horizontal illuminance level. Since we mostly see the vertical surfaces, the vertical illuminance is also important criteria unless it does not create a discomfort glare (9).
2.2. Human Factors in Lighting

The discovery of electric lighting and the improvements for light sources had an impact on the structure of the environments and societies. It is another fundamental point to connect the lighting to the human aspect to provide the expectations for safety and security. It is a well-known fact that darkness can be a reason to associate it with unsafe and unsecure space for human being. In that sense, lighting has an essential role for providing the visual information and showing the surroundings to make the pedestrians perceive the urban space as safe and secure especially at night time. It also gives the needed information to identify the other pedestrians, space navigation and other elements in the nearby space. Pedestrians can feel safer if they can see the surroundings to understand where they are and is there anyone in front of them as a threat (10).

In general, urban lighting can be examined in five different concepts to go deeper in relation to the human aspect.

1. Safe Movement

Although for walking along a path needs low amount of light, it is a necessary to have contrast to notice and avoid the obstacles on the footpath or have to escape routes for emergency situations in urban environments (11).


In order to find the way to go where you want it is a necessary thing that to be aware of where you are and which direction you need to follow. Especially for residential areas, pedestrians are in general the ones are using the path while being familiar with it, lighting might not be a critical factor to feel safe and secure, but it could improve it. However, in the case of being unfamiliar with the path, pedestrians need more visual information which might be improved within lighting to find their routes easily and safely. Visual information could be the visual references as it is classified into five types of city elements (12);

- Paths

These are the streets, sidewalks, routes and alleys. They could be the predominant element of the image of city as a perceived visual reference by pedestrians.

- Edges

They are the boundaries as walls, buildings, and shorelines, streets, overpasses, etc. while being real or perceived.

- Districts

These are the larger size areas of the city like city blocks or neighbourhoods.

- Nodes

The places offer the person in them multiple perspectives of the other core elements, such as intersections, city centres and town squares.
• Landmarks

Points of reference person cannot enter into; these are high buildings, signs, stores, mountains, public art.

Lighting is an inseparable part of building cities by focusing the human perception in urban environment. A luminous composition should be coherent with the urban space to make pedestrians perceive it better.

3. Visual Comfort

The visual comfort concept includes the aspects of the eye adaptation to the light and glare free situation of the urban environment. Human visual system has a sensitivity and limitation to adapt itself to the changing lighting levels, in fact it does not happen instantly. The visual adaptation might be very important to perceive the surroundings and threats and to understand the transitions of spaces having different illumination levels. The high contrast between two different illuminated spaces can show the less illuminated space as darker than the reality (13).

4. Facial Recognition

The personal spaces around a person might be affect the comfortability and safety feeling of the people (14). Lighting might be an important factor to show the people in differently such as a silhouette or readable face, which might affect the perception and recognition of the other people (15).

5. Feeling of Safety

Since the elderly people might feel unsafe more than young people, the physical capacity could be a reason for perceived safety (16). Therefore, the surroundings should be readable and indicate the visual references for escaping routes. This addresses the importance of lighting conditions for the actual or perceived safety especially in the darkness, although there other factors to contribute that.
2.3. The Integration of New Lighting Technology

Since the world population has been increasing very fastly and due to growing urbanization, the cities are facing with the need of new technologies and systems to contribute the urban planning and management. For the increasing demand for sustainable solutions, currently the best choice is to incorporate with the new information and technology systems for more connected public environment while improving the comfortability, aesthetic appearance and livability of the cities.

Last technological developments showed that the LED solutions are the best choice for now in terms of their flexibility, maintenance and energy efficiency. Also, the new smart control systems are suitable to incorporate with these systems. Therefore, the idea was that the new lighting systems could do more than the old systems in terms of the influences on the surroundings and environment of the systems with the new technologies. Generally, switching options for existing electric circuits were limited to on/off settings that do not really offer control (17). The most important development is that lighting can be controlled centrally but at the same time locally to set the different required time and scenarios for certain urban spaces (18). The easiest and most traditional way is to simply switch the lights off completely when nobody’s around. Though, in urban areas with parks and other public spaces, this is hardly a good idea as people then stop visiting the area after dark. The trick is to design a lighting control system that can optimize lighting levels but regarding energy savings as well as visual comfort and safety (19).

What current technology offers;

1. Motion Sensor

It detects the movement of the people to light itself up for required performing tasks such as walking, jogging, etc.

2. Intensity Control / Dimming

It can change the intensity level of the luminaire and set it according to the requirements of the time and the movement of the pedestrians.
3. Configurations / Scenarios

It can control the different luminaires separately or as a group based on the data taken from the sensors for different chosen variable scenarios which can be changed later on by the authorities.

Graph 1. - Graph showing how the control system works.

Fig.9.- Image showing the grouping system.

Fig.10. - Image showing the motion sensation and dimming.

Diagram:

- Default Mode
- Detection
- Receive
- Alternate Mode
- Transmit
- Time

Flowchart:

- Default Mode -> Detection
- Detection -> Receive
- Receive -> Time
- Time -> Transmit
- Transmit -> Alternate Mode
- Alternate Mode

Graph 1. - Graph showing how the control system works.
3. Methodology

This study will try to answer the question of “How a networked public lighting can be created in order to enhance the needs of the pedestrians in Fredhällspark?”

The research is based on my observations, a qualitative approach and a quantitative approach. The aim with my observations was to understand the site, the existing lighting conditions and the usage functions of the space. Also, a survey is conducted with 50 people using the site to understand what they want and how they think about the atmosphere and the lighting conditions. For quantitative approach, the luminance levels and contrast values were measured to evaluate the site.

3.1. Observations

3.1.1. Site Analysis

3.1.1.1. Location

The site is located at Fredhäll in Kungsholmen district, Stockholm, Sweden. It is located on the southwestern part of Kungsholmen. It borders in the east to Marieberg and in the north towards Kristineberg. Also, it is bounded by the Essingefjärden water area in the south. The site under analysis is a pedestrian transition point from the park side in the ground level to the bridge side in the upper level.
The studied area is near side of the main road along the bridge and sea. It connects the pedestrian path near to bridge and the pedestrian path goes to the Fredhäll park by surrounding with trees. From the highest point of the site, the sea and the beach part are visible, although it is obstructed by trees. The access points are showed in the Fig.16., which were the intersection points for pedestrians and cyclists. Around of the site, there are some residential buildings which are obstructed by main road. Also, it is close to Kristineberg Metro Station, it is reachable from the tunnel under of the main road. Close to the seaside, there
The pedestrians are divided into 4 categories based on their performing activities. The users are dog walkers, walkers/joggers, cyclists and families. Mostly, the pathway is used as a transition point between the park and bridge.

is a boat club, which is very active place especially during warm weather time and weekend times. The site involves the old luminaires on staircase, and almost new luminaires which were installed in 2015. The Fredhäll park is a green area with an open space, which is in usage for children to play and for picnic events for the residents. The general atmosphere of the site has a good ambiance with sea view and park area.

3.1.1.3. Users

The pedestrians are divided into 4 categories based on their performing activities. The users are dog walkers, walkers/joggers, cyclists and families. Mostly, the pathway is used as a transition point between the park and bridge.

In general, the site is used for certain activities which are;

1. Exercise such as jogging, walking, cycling.
2. Relaxation through walking for families or dog walkers.
3. Randomly passing from the path.
### 3.1.1.4. Peak Hours

The intensity of the usage of the path for pedestrians is divided into three different categories, which are heavy, moderate and less in four different time durations per a day. As it is shown in the Graph 3., the mostly the path is in usage at between 7-9 am and 5-7 pm.

### 3.1.1.5. Movement

The movement map is showed in the Fig.17., with two different types of the usage as pedestrians and cyclists.

### 3.1.2. Lighting Analysis

The site has three different types of lighting fixtures which are shown in Fig.18., PL-01 is to illuminate the pedestrian path along with bridge, PL-02 is to illuminate the transition point including the stairs and pathway. PL-03 is to illuminate the pathway coming to the transition point with control systems to detect human movement.
Also, the section drawing is also shown in Illustration 1., to analyze the lighting direction and human scale in the site.

As it is shown in Fig.19., PL-02 has an old type lighting light source, which is not in production anymore. PL-03 is a new installed lighting fixture with OWLET control system, which gives sensor detection to increase the light amount when a pedestrian close to the path, and they are connected to cloud system to communicate each other.
3.2. Qualitative Approach

The aim of this study to understand what people want, what will bring them to this site and how they think about the perception of the atmosphere and lighting conditions in the atmosphere. The study was conducted with 50 people based on the questionnaires. *(For more detailed information, see the Appendix A.)*

3.3. Quantitative Approach

For quantitative results; light levels, colored images were taken in the studied area. The illuminance measurements were taken by The Hagner Digital Luxmeter EC1, to calculate the horizontal lux levels at the site and the contrast values between the lit and dark points in the defined three parts; park, staircase and bridge.
4. Results

The results from the questionnaires conducted with 50 people are showed in the Graph 4. - Graph 11. It was an interesting finding that although 40% of the users define the light enough at night time, 40% of them found hardly

Graph 4. - Pie chart showing percentage of male and female.

Graph 5. - Pie chart showing percentage of age.

Graph 6. - Pie chart showing percentage of user type.

Graph 7. - Pie chart showing percentage of usage frequency.

Graph 8. - Pie chart showing percentage of safety.

Graph 9. - Pie chart showing percentage of light perception.

Graph 10. - Pie chart showing percentage of seeing obstacles.

Graph 11. - Pie chart showing percentage of recognizing faces.
to feel safe. Another important finding was 55% of the users describe partly to figure out the objects and obstacles, 38% of them describe hardly to recognize people’s faces during night time. This study showed that despite the light intensity feeling is enough, the lighting conditions have a high contrast and glare problem, which can be highly associated with the perception

How do you feel about the atmosphere of this path?

How do you feel about the atmosphere of this path?

How do you feel about the atmosphere of this path?

How do you feel about the atmosphere of this path?
of safety.

Results from the “Questionnaire 2” (See the Appendix B) showed that mostly people feel neutral about the atmosphere of the space. However, as it is shown in Graph 12. - Graph 18., 60% of the users evaluate the private option at 2 level comparing to the public option. Moreover, 35% of them evaluate the space close to the unsafe and boring. It was an interesting point that since they mentioned for higher level of the space there is a nice view which attracts them and give sense of calmness with the surroundings such as trees at daytime while they are more able to see and understand what is happening around of them. However at night time, the users are closely to lose their sense of safety and use rarely the space because of the feeling of unknown.

As it is shown in the Fig.20. and the Graph19., the results for the horizontal illuminance values pointed out that

<table>
<thead>
<tr>
<th>Illuminance</th>
<th>Area A Path</th>
<th>Area B Transition Zone</th>
<th>Area C Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>4 Lux</td>
<td>10 Lux</td>
<td>12 Lux</td>
</tr>
<tr>
<td></td>
<td>12 Lux</td>
<td>4 Lux</td>
<td>8 Lux</td>
</tr>
<tr>
<td>Min</td>
<td>24 Lux</td>
<td>22 Lux</td>
<td>20 Lux</td>
</tr>
<tr>
<td></td>
<td>20 Lux</td>
<td>80 Lux</td>
<td>26 Lux</td>
</tr>
<tr>
<td>Average</td>
<td>12 Lux</td>
<td>16 Lux</td>
<td>12 Lux</td>
</tr>
<tr>
<td></td>
<td>16 Lux</td>
<td>45 Lux</td>
<td>12 Lux</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60 Lux</td>
<td>60 Lux</td>
</tr>
</tbody>
</table>

Fig.20. - The Image showing the illuminance levels in site map

Graph 19. - Graph showing the horizontal illuminance values in different areas
Area A with the new installation is very uniform and enough values (20). For Area C, the lighting condition is not uniform while considering the minimum and maximum values, which is the result of the road lighting. However, it gives the enough illuminance. For the Area B, which the place of transition, the study showed that especially B3 area has high differences in the values, since the maximum value is 80 lux.

As it is shown in the Fig.21. and Fig.22. (For more images, see the Appendix C), there are huge luminance differences between the task areas and the surroundings while using the LBR Scale to evaluate the brightness contrast (21).

In general, the results showed that too bright light levels in the task areas could result in the high contrast with the surroundings, which is not suggested. Although hierarchy in lighting is appreciated, more uniform lighting conditions are preferable for visual adaptation in order to avoid the imbalance between the task area and surroundings.
5. Conceptual Design

Based on the collected information from the background research, the analyses and results of the study, the lighting design aims to take a base of the views of pedestrians which are divided into two categories as it is shown in the graph.

- Ground level from the park side.
- The upper level from the bridge side.

It is showed that there is need of a connection & transition between these zones, lighting design could be a connected element through them which gives a huge design potential to create a more connected, inviting and safely environment. According to this base, the lighting design aims to follow some strategies which are;

- To create a smooth transition between the ground and upper level of the site in terms of the illuminance levels and uniformity.
- To use the surroundings as a tool since they have a huge impact on the pedestrians to notice the possibility of threat and occurring activities around of them, also to create an inviting environment.
- To clarify the need of ambiance and task lighting in order to distinguish and create a hierarchy between the two different sides of the space.
- To achieve a smart controllable lighting solution for sustainability and future solutions by creating different scenarios based on the users needs.

5.1. Design Development

Creating a space emphasizes the performing task in the area, which is having a walk or cycling as a pedestrian with a comfortable and safe journey. To make the space more uniform and also to highlight the surroundings smoothly will reveal the character of the space. For more smooth transition in the upper level, to increase the illuminance levels will create a balance between two different zones and make the

Graph 20. - Graph showing the lighting design vision schema
adaptation of the pedestrians easy to the more lit bridge side. For the ground level, diffused light blending to the atmosphere will create a combination with lower intense light in the path while providing more calm feeling in balance with the general atmosphere of the space. With this design approach, the space is divided into two categories in terms of lighting types; which are task lighting for the pedestrian path and ambiance lighting for the surroundings, as it is shown in the Fig.37.

For task lighting in the path, the rail lighting fixtures will be used to ensure having enough illuminance in horizontal level and avoid the glare possibility depends on from which side the pedestrian is approaching. As it is shown in the results, from different views of pedestrians, they could need different intensity levels for eye adaptation.

For ambiance lighting, to up light the trees will create a calm atmosphere and also enhance the visibility of the surroundings.

Since the different views of the pedestrians and the different needs for changing seasons and time are very critical aspects, the lighting design will be based on the different scenarios can be controlled with smart technologies. In the urban context, the environment should be lit to invite people and give the perception of safety. Therefore, trees will be lit in lower intensity, but they will have higher intensity when a pedestrian is approaching through the smart sensors and communicating each other. This system also will allow to create different usage scenario’s depends on where the user is for possible different occasions and also future developments.
Moodboard

Fig. 38. - Image showing pedestrian lighting design example 1

Fig. 39. - Image showing pedestrian lighting design example 2

Fig. 40. - Image showing pedestrian lighting design example 3

Fig. 41. - Image showing pedestrian lighting design example 4

Fig. 42. - Image showing uplighting tree design example 1

Fig. 43. - Image showing rail lighting fixture detail
5.2. Design Proposal

Fig. 44. - Image showing lighting design proposal 1
Fig. 45. - Image showing lighting design proposal 2
Fig. 46. - Image showing lighting design proposal 3
Fig. 47. - Image showing lighting design proposal 4
6. Discussion

It is the aim of this thesis to analyse and develop a lighting design solution by using the smart technologies as a way of serving the different user needs in different times and seasons. The idea was to emphasize the significant role of the site analysis since each urban environment has their own unique characteristics for integrating the technologies by ensuring the pedestrian needs.

Based on the site analysis and through results, study showed that there is a need for smooth transition between the park and bridge side by prioritizing the different viewpoints of the pedestrians. The user research study pointed out that pedestrians are prone to feel more unsafe and uncomfortable in the transition zone, where the existing lighting fixtures are the oldest ones. The results also showed that the transition zone has an inappropriate lighting with the lack of lighting from the surroundings and non-uniform distribution of the light sources in there. As it is investigated in the background research, more illumination does not create better lighting conditions since the glare can occur when the light is to bright within the pedestrian’s field of view comparing to general ambiance lighting. In fact a fast shift low to high luminance levels results in significant difficulty, since it can affect the perceived brightness while having visual adaptation difficulty (22). Although there are other factors to contribute that the difficulty in visual adaptation has an influence on the user’s confidence strongly.

Moreover, with the differentiation between the height levels of the space, as it is also explained in the background research, ‘edges’ can change the user perception while creating a boundary. Also the perception of boundary is supported with the surroundings as high and dark trees, while it gives an abandoned and enclosed appearance to the space. Through the user surveys and measurements it is clear facts that the transition zone creates a perception of standing under the spotlight while the others watching you but the pedestrian is not able to see them. Better visibility for occurring activities in the surrounding context does matter to feel safe and secure.

Also, perceived brightness can change the sense of depth and size of the space while showing it different than the reality. For revealing the character of the space, up lighting the trees is suggested as a solution.

This study is tried to develop a solution for different viewpoints of pedestrians, which creates a need for smart lighting solutions to ensure different type of scenario’s for more sustainable and livable urban environments. Since the urban environments are very dynamic and includes different usage patterns, the lighting solutions should point out the adaptation of the technologies through human centered design approach. Especially the site-specific lighting solutions could be the basis of the success in order to be up to date to the different times and seasons and also to be operator & environmental friendly (23).
7. Conclusion & Limitations

The scope of the investigation is to provide the technological needs and requirements of the future urban environments by prioriting the pedestrians through site-specific lighting design solutions.

The intentions are aimed in the beginning of the study;

- to create a safe and secure urban space for pedestrians.

- to integrate the smart lighting technology in relation to the user requirements which are comfortability, safety and perception.

- to achieve a lighting design solution which is suitable / open to possible technology adaptations for future.

- to achieve a certain lighting control / settings for sustainable requirements.

Since enhancing the user needs in the urban context for better illumination does not mean adding more light, this study is tried to take the first step by creating more uniform lighting levels while making the surroundings more visible. Some urban elements such as trees, road lighting and buildings can also affect the perception of safety and security although lighting has a fundamental role with that. When planning and designing a certain site, these factors also should be taken into consideration carefully.

Moreover, the smart systems for lighting solutions include very broad approaches to the urban context and it is matter of correct implementation with a testing process. In that sense, some practical details and possibilities of different scenarios are to be considered conceptual stage and need further investigation. The lighting design proposal has to be developed with testing, implementation and user research for scenarios on the site.


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LIST OF FIGURES

Fig.1.

Fig.2.

Fig.3.

Fig.4.

Fig.5.

Fig.6.

Fig.7.

Fig.8.

Fig.9.

Fig.10.

Fig.11.
Site Location. Retrieved April/May, 2018, from Google Maps.

Fig.12.

Fig.13.

Fig.14.

Fig.15.

Fig.16.

Fig.17.

Fig.18.

Fig.19.

Fig.20.
LIST OF FIGURES

Fig. 21. The luminance photography 1 [Personal photograph taken in Stockholm with OpticaLight mobile application]. (2018, April-May 27).

Fig. 22. Evaluation of brightness contrast 1. [Personal photograph taken in Stockholm]. (2018, April-May 27).

Fig. 23. The luminance photography 2 [Personal photograph taken in Stockholm with OpticaLight mobile application]. (2018, April-May 27).

Fig. 24. Evaluation of brightness contrast 2. [Personal photograph taken in Stockholm]. (2018, April-May 27).

Fig. 25. The luminance photography 3. [Personal photograph taken in Stockholm with OpticaLight mobile application]. (2018, April-May 27).


Fig. 27. The luminance photography 4. [Personal photograph taken in Stockholm with OpticaLight mobile application]. (2018, April-May 27).

Fig. 28. Evaluation of brightness contrast 4. [Personal photograph taken in Stockholm]. (2018, April-May 27).

Fig. 29. The luminance photography 5. [Personal photograph taken in Stockholm with OpticaLight mobile application]. (2018, April-May 27).

Fig. 30. Evaluation of brightness contrast 5. [Personal photograph taken in Stockholm]. (2018, April-May 27).

Fig. 31. The luminance photography 6. [Personal photograph taken in Stockholm with OpticaLight mobile application]. (2018, April-May 27).

Fig. 32. Evaluation of brightness contrast 6. [Personal photograph taken in Stockholm]. (2018, April-May 27).

Fig. 33. The luminance photography 7. [Personal photograph taken in Stockholm with OpticaLight mobile application]. (2018, April-May 27).

Fig. 34. Evaluation of brightness contrast 7. [Personal photograph taken in Stockholm]. (2018, April-May 27).

Fig. 35. The luminance photography 8. [Personal photograph taken in Stockholm with OpticaLight mobile application]. (2018, April-May 27).

Fig. 36. Evaluation of brightness contrast 8. [Personal photograph taken in Stockholm]. (2018, April-May 27).

Fig. 37. Different lighting areas [Personal illustration created in Stockholm]. (2018, April 27).


Fig. 39. IGuzzini Trick - Bro over Næstved station. (n.d.). Retrieved April/May, 2018, from https://i.pinimg.com/originals/b6/88/5a/b6885aa8d0462e3a2b6377a643cd11ff.jpg

Fig. 40. Pedestrian Bridge. (n.d.). Retrieved April/
LIST OF FIGURES

Fig. 41. Landscape Lighting Design. (2017). Retrieved April/May, 2018, from https://showyourvote.org/landscape-lighting-design-ideas/

Fig. 42. Landscape Lighting Design. (2017). Retrieved April/May, 2018, from http://www.ideas4landscaping.com/?hop=schmip

Fig. 43. Q-lights LED illuminated handrail. (n.d.). Retrieved April/May, 2018, from https://www.buildingdesignindex.co.uk/entry/110139/QRailing/Qlights-Spotlight-LED-illuminated-handrail-systems/

Fig. 44. Lighting Design Proposal Sketch 1 [Personal illustration created in Stockholm]. (2018, April 27).

Fig. 45. Lighting Design Proposal Sketch 2 [Personal illustration created in Stockholm]. (2018, April 27).

Fig. 46. Lighting Design Proposal Sketch 3 [Personal illustration created in Stockholm]. (2018, April 27).

Fig. 47. Lighting Design Proposal Sketch 4 [Personal illustration created in Stockholm]. (2018, April 27).

Fig. 48. Lighting Design Proposal Lighting Layout [Personal illustration created in Stockholm]. (2018, April 27).

Fig. 49. Lighting Design Proposal Elevation [Personal illustration created in Stockholm]. (2018, April 27).
Graph 1.  

Graph 2.  

Graph 3.  
The Graph of Intensity of Pedestrian Traffic in Different Times of Day. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 4.  
Pie chart showing percentage of male and female. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 5.  
Pie chart showing percentage of age. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 6.  
Pie chart showing percentage of user type. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 7.  
Pie chart showing percentage of usage frequency. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 8.  
Pie chart showing percentage of safety. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 9.  
Pie chart showing percentage of light perception. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 10.  
Pie chart showing percentage of seeing obstacles. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 11.  
Pie chart showing percentage of recognizing faces. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 12.  
Graph showing evaluation of private-public. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 13.  
Graph showing evaluation of interesting-monotonous. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 14.  
Graph showing evaluation of tense - relax. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 15.  
Graph showing evaluation of safe-unsafe. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 16.  
Graph showing evaluation of pleasant-unpleasant. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 17.  
Graph showing evaluation of exciting - boring. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 18.  
Graph showing evaluation of welcoming - rejecting. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 19.  
Graph showing the horizontal illuminance values in different areas. [Personal illustration created in Stockholm]. (2018, April -May)

Graph 20.  
Graph showing the lighting design vision schema. [Personal illustration created in Stockholm]. (2018, April -May)
APPENDIX A

Questionnaire 1

1. Gender:
   Male □     Female □

2. Age:
   <20 □   20-40 □   40-50 □   >60 □

3. Usually, you use this path as:
   A Pedestrian □   A cyclist □

4. How often do you use this path?
   Everyday □   Once a week □   Once a month □   Rarely □

5. Do you feel safe walking on this path during night time?
   Absolutely □   Partly □   Hardly □   Not at all □

6. Is the light enough for what you need to see during night time?
   Absolutely □   Partly □   Hardly □   Not at all □

7. Do you easily figure out objects and obstacles during night time?
   Absolutely □   Partly □   Hardly □   Not at all □

8. Do you easily recognize other people's faces during night time?
   Absolutely □   Partly □   Hardly □   Not at all □
Questionnaire 2

1. How do you feel about the atmosphere of this path?

<table>
<thead>
<tr>
<th>Private</th>
<th>Interesting</th>
<th>Tense</th>
<th>Safe</th>
<th>Pleasant</th>
<th>Exciting</th>
<th>Welcoming</th>
<th>Public</th>
<th>Monotonous</th>
<th>Relax</th>
<th>Unsafe</th>
<th>Unpleasant</th>
<th>Boring</th>
<th>Rejecting</th>
</tr>
</thead>
</table>
Fig. 29 - Image showing the luminance photography 5

Fig. 30 - The image showing evaluation of brightness contrast.

Fig. 31 - Image showing the luminance photography 6

Fig. 32 - The image showing evaluation of brightness contrast.

Fig. 33 - Image showing the luminance photography 7

Fig. 34 - The image showing evaluation of brightness contrast.

Fig. 35 - Image showing the luminance photography 8

Fig. 36 - The image showing evaluation of brightness contrast.
Fig 48 - The image showing the new installation lighting layout as a schema.