

# P R O J E C T   K U N G S H O L M S   S T R A N D

## ADVANCED INDIVIDUAL CONTROL OF OUTDOOR LIGHTING

Research evaluation, results and conclusions



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KTH

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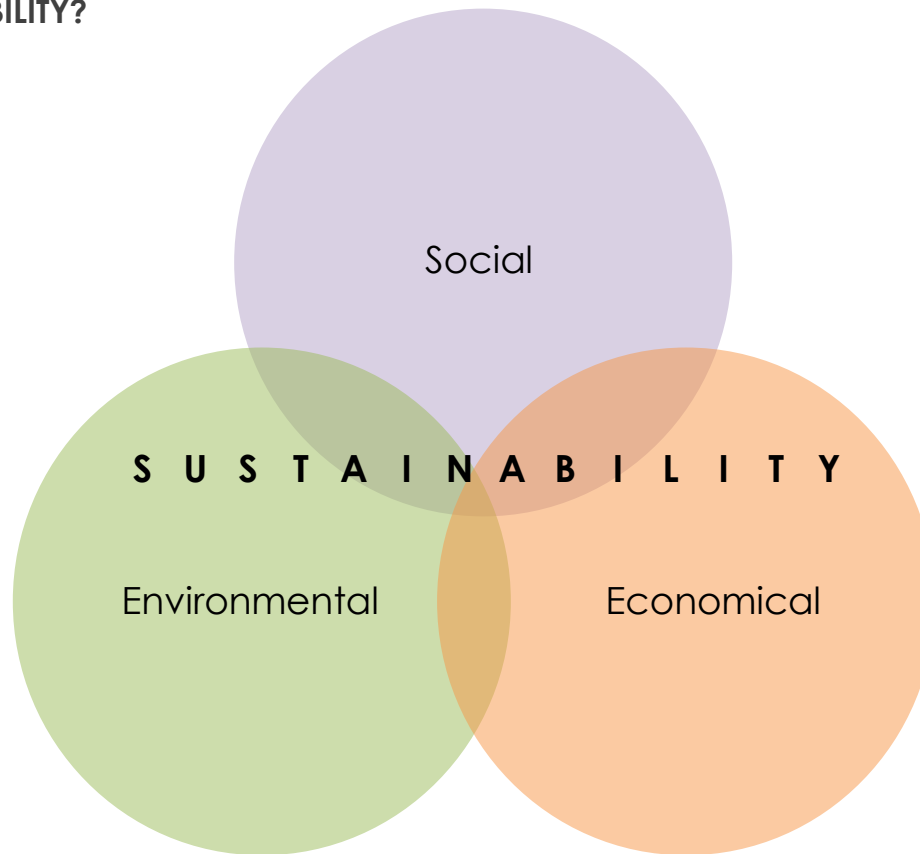
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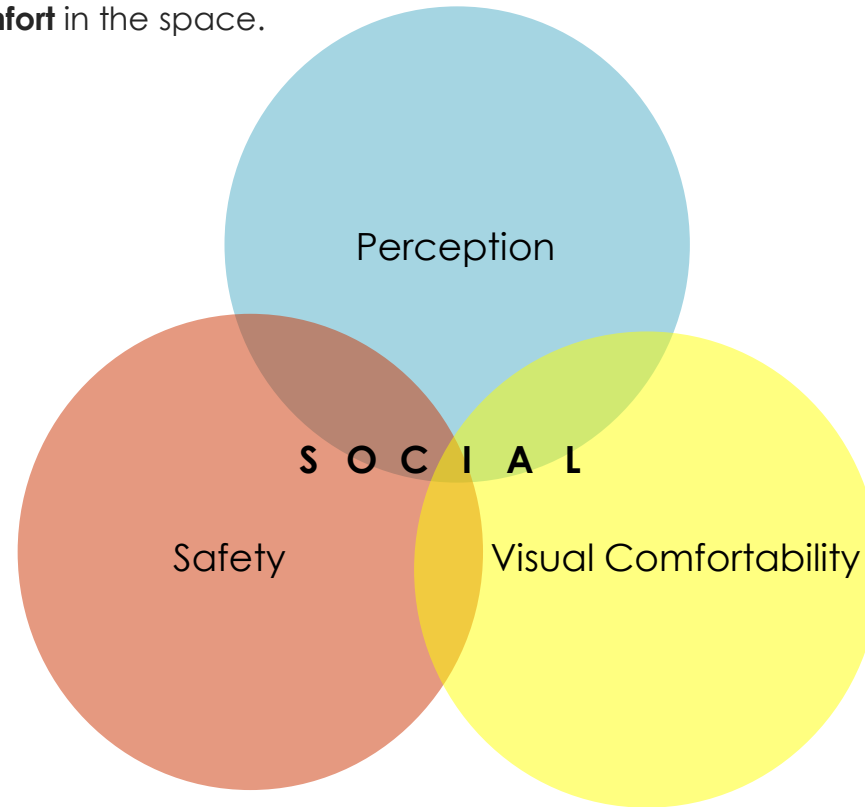
# 1 INTRODUCTION

- **Sustainable solutions** are the current trend in the industry; lighting industry is no exception. Sustainable solutions are no longer a choice, but need of the hour.

- **WHAT IS SUSTAINABILITY?**

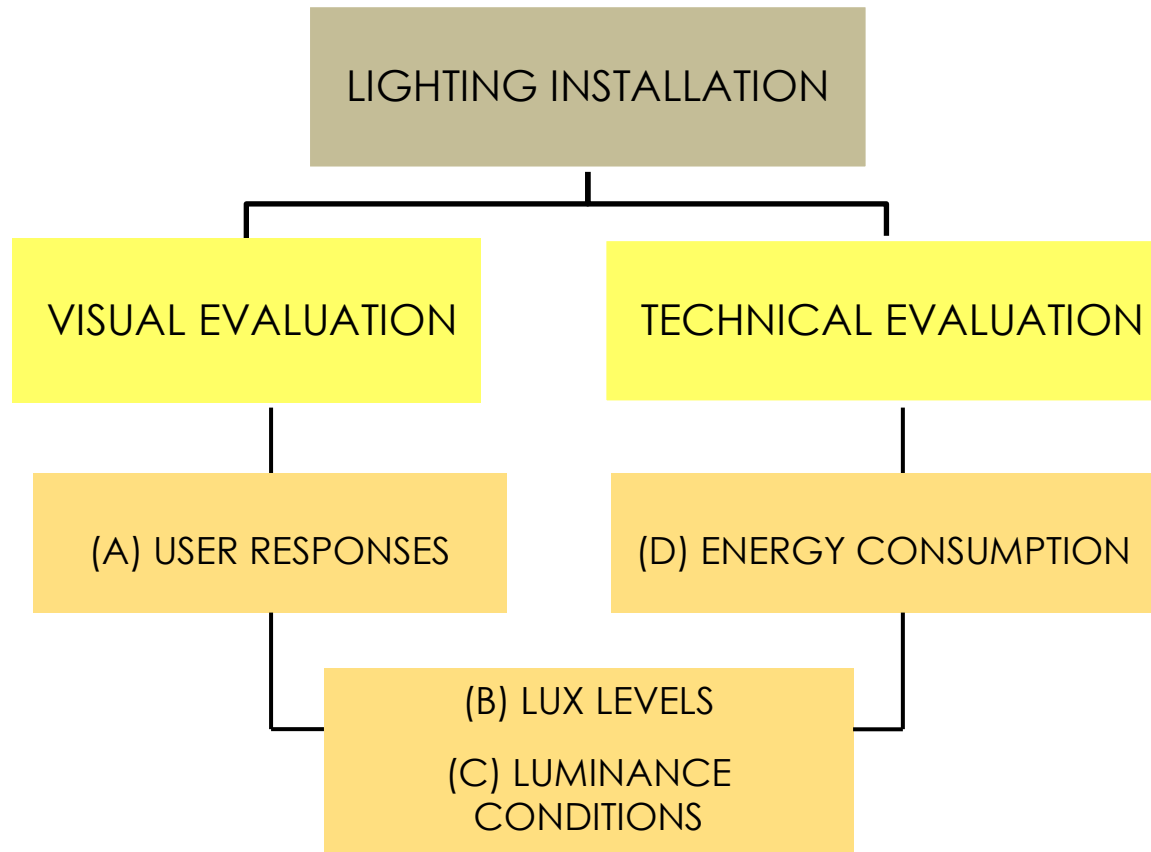


**AIM** - The purpose of the study was to know if lighting control system (example of sustainable lighting solution) can be implemented in an urban environment without jeopardizing with **human perception, safety** and visual **comfortability**; thereby finding a **balance between the energy usage and user comfort** in the space.



- Key areas of human factors analysed – **PERCEPTION** , **SAFETY** and **COMFORTABILITY**

## 2 METHODOLOGY OF EVALUATION



### 3 PROJECT RESEARCH

- **SITE ANALYSIS**

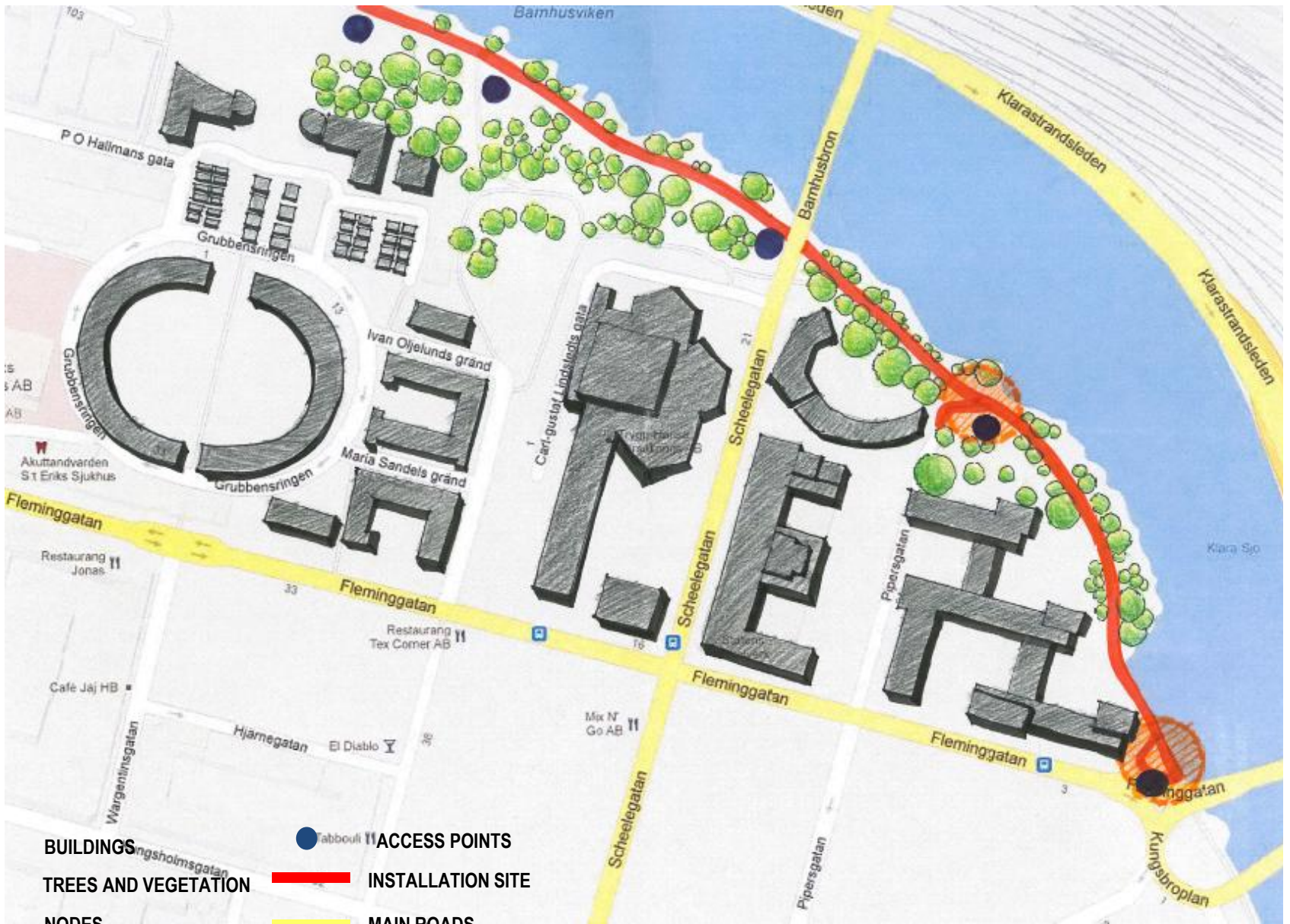
- **Introduction**

- **Site :**

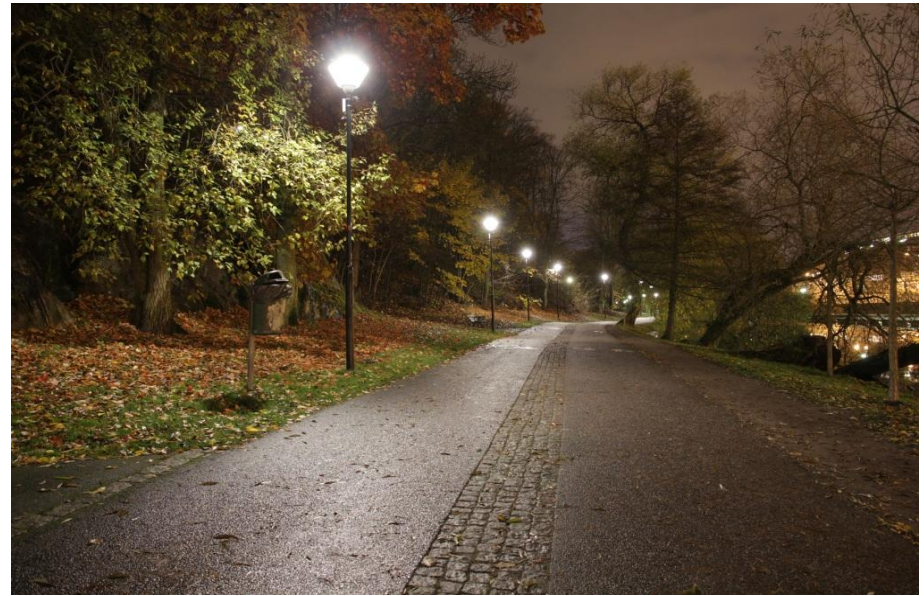
Kungsholmsstrand

- A stretch of 750 mts
- Pedestrian and bicycle pathway
- 34 street light poles
- LED fixtures with modern lighting control systems





- BUILDINGS
- TREES AND VEGETATION
- NODES
- ACCESS POINTS
- INSTALLATION SITE
- MAIN ROADS





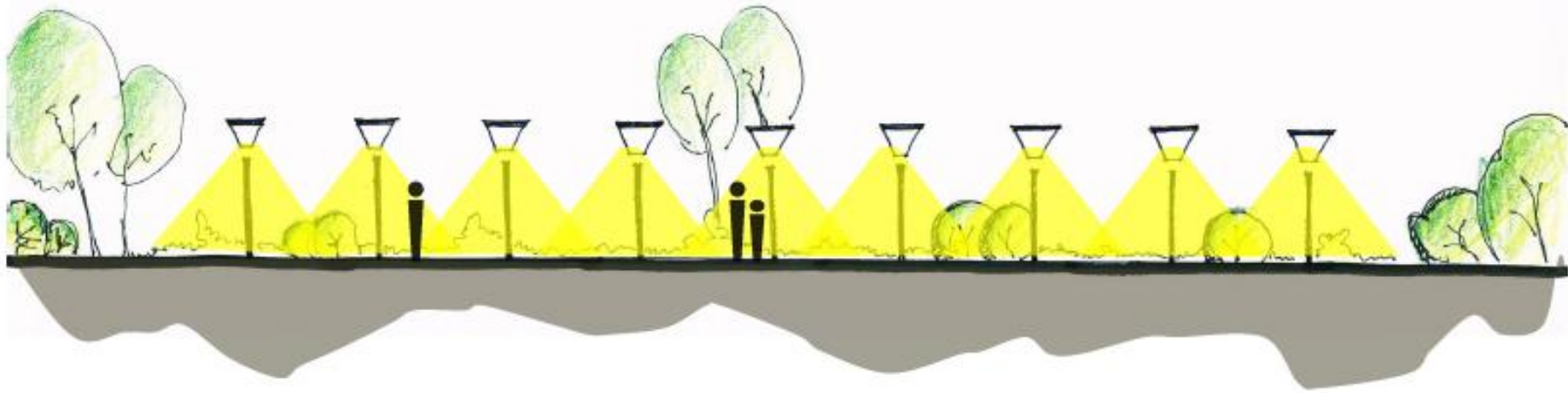
- Test group of 10 – 12 people decided minimum light levels with visual judgement
- Lowest light level – **level 5** (50% light output) ; Highest light level – **level 10** (100% light output) ; end poles at **level 7** (70 % light output) all the time.
- 5 different scenarios over a period of five weeks
- On site interviews with people for feedback of installation - 21 number of responses for each week/ scenario
- The questions concentrated on human vision, safety and perception and included range of ages, genders and the mode of transport by the users

Table showing the test scenarios :

<i>Scenario</i>	<i>Low Power level</i>	<i>High Power level</i>	<i>Number of poles</i>	<i>Timer setting (s)</i>
<i># 0</i>	<i>10</i>	<i>10</i>	<i>All</i>	<i>- NO -</i>
<i># 1</i>	<i>5 ( 7 for first 3)</i>	<i>10</i>	<i>All</i>	<i>120</i>
<i># 2</i>	<i>5 ( 7 for first 3)</i>	<i>8</i>	<i>All</i>	<i>120</i>
<i># 3</i>	<i>5 ( 7 for first 3)</i>	<i>10</i>	<i>7 (3+1+3)</i>	<i>120</i>
<i># 4</i>	<i>5 ( 7 for first 3)</i>	<i>10</i>	<i>7 (3+1+3)</i>	<i>60</i>

## (A) USER RESPONSES EVALUATION

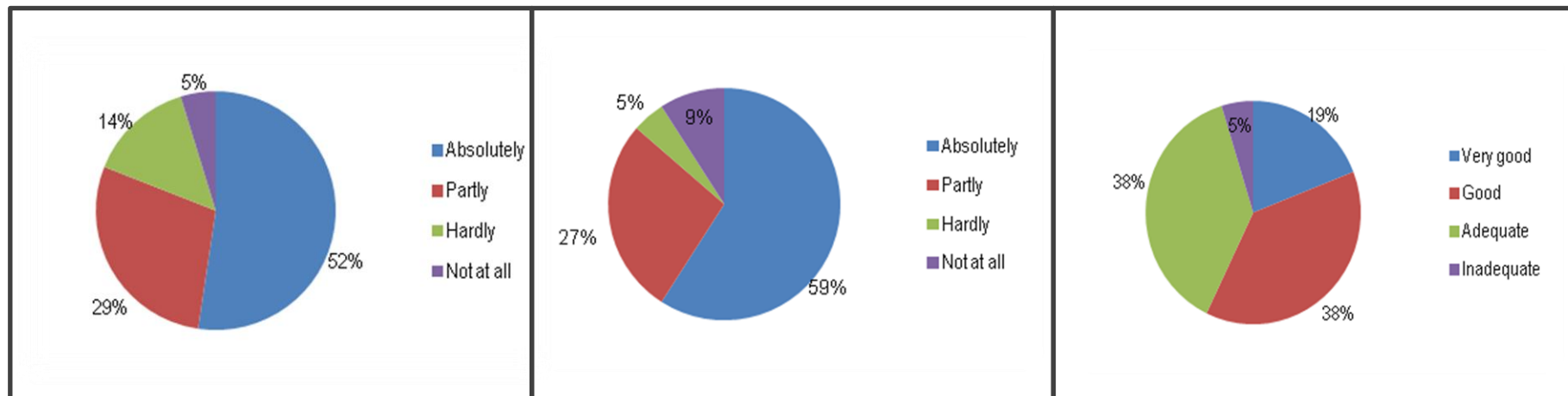
### A.1 STABLE LIGHTING SITUATION WITHOUT LIGHTING CONTROL SYSTEM



#### SCENARIO #0

- Low power level – 10
- High power level – 10
- Stable condition with constant light all the time.

## (A) USER RESPONSES EVALUATION – SCENARIO #0



SAFETY

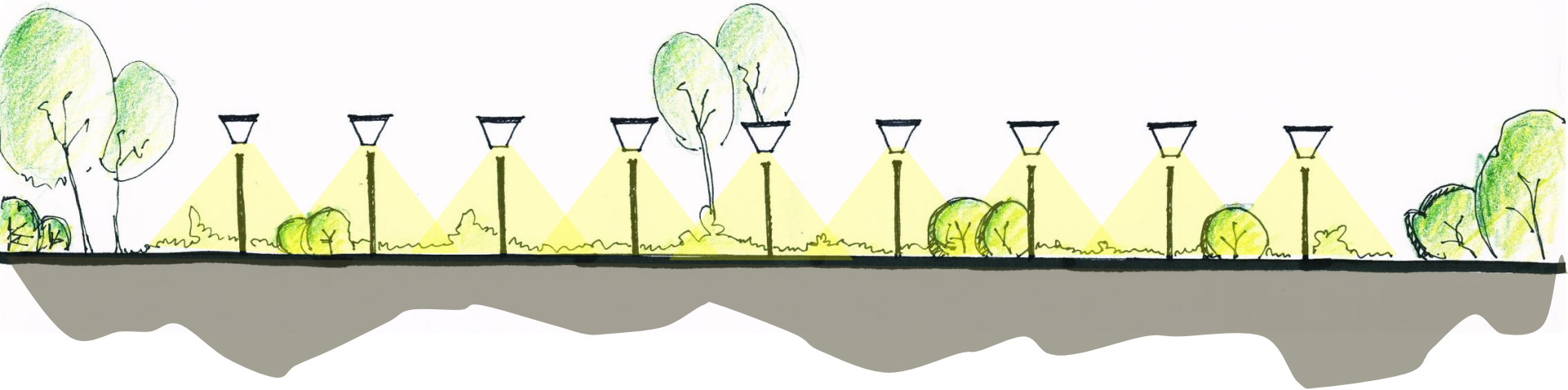
VISUAL COMFORTABILITY

PERCEPTION

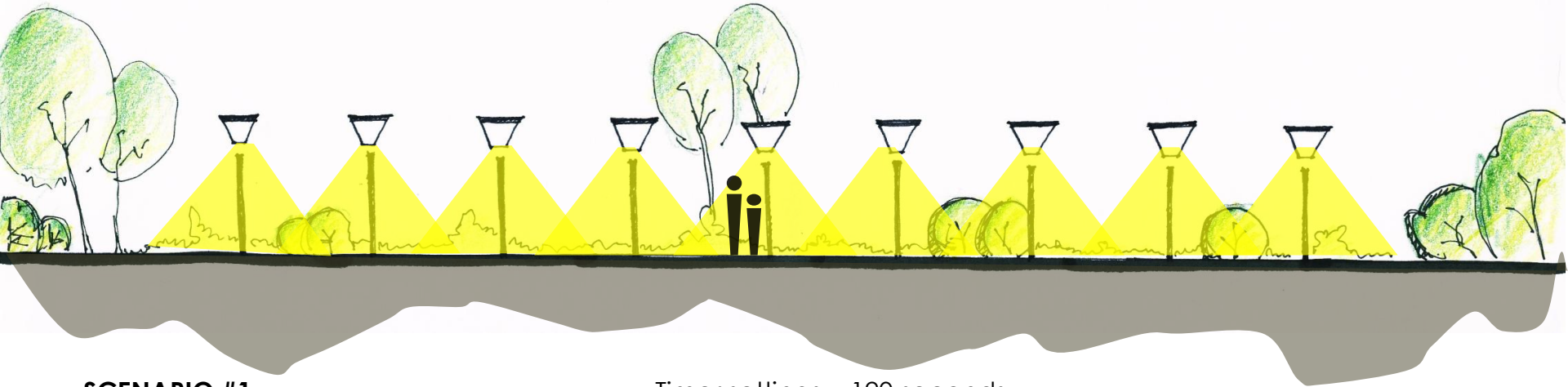
### SCENARIO #0

- Too bright light levels – high contrast and uncomfortable
- Women feel more unsafe compared to men; although the reasons were lack of people and time of the day
- Some of them associate light levels with safety.
- Surrounding light important for better perception and safety – widens the perception for the field of vision
- Color of light influences perception – yellow light on the other side of the water wasn't preferred.
- Bicyclists were found to be comfortable with the idea; control systems acted like a warning signal for them

## A.2 LIGHTING SITUATION WITHOUT ANY PRESENCE OF PEOPLE



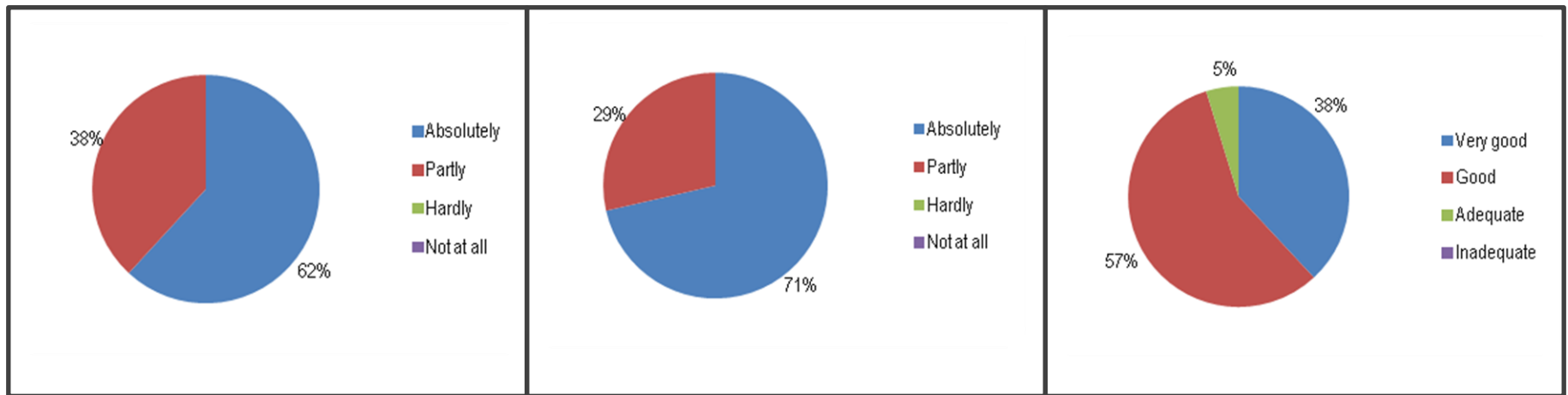
## A.3 LIGHTING SITUATION WITH PRESENCE OF PEOPLE



### SCENARIO #1

- Low power level – 5
- High power level – 10
- Timer settings – 120 seconds
- No. of poles – All
- End 3 poles of the stretch at level – 7 all the time

## (A) USER RESPONSES EVALUATION – SCENARIO #1



SAFETY

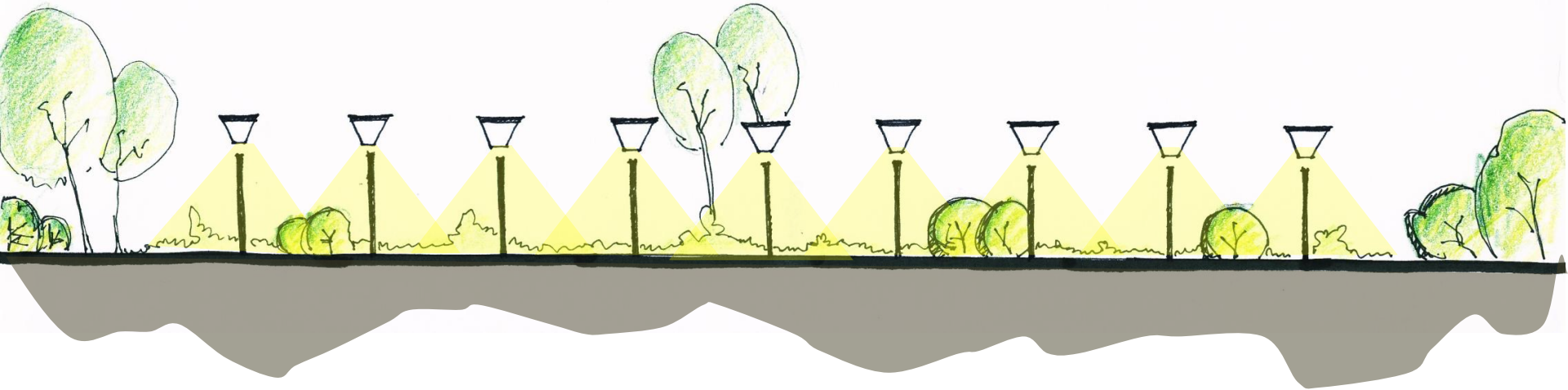
VISUAL COMFORTABILITY

PERCEPTION

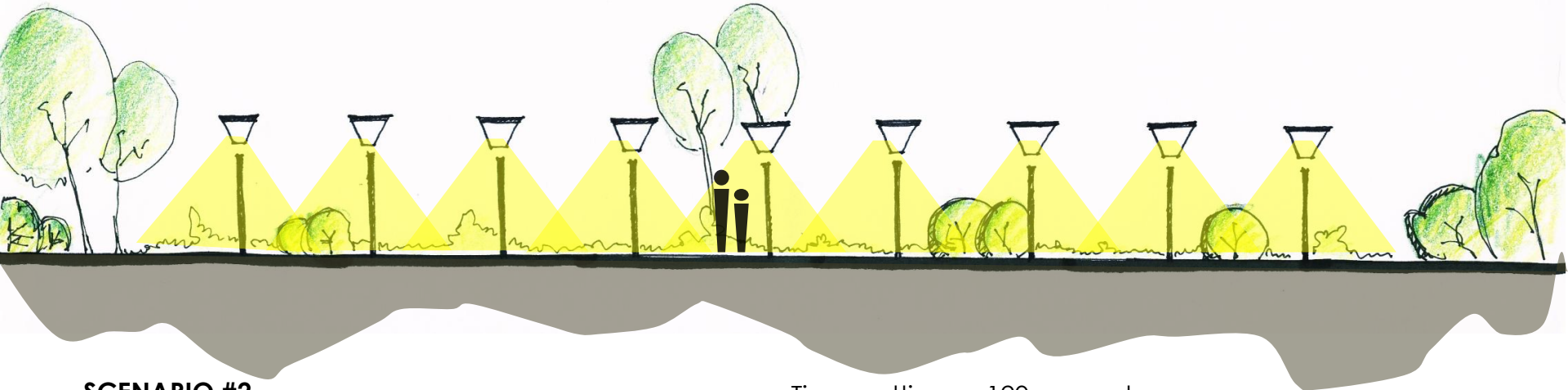
### SCENARIO #1

- Too bright light levels – high contrast and uncomfortable; some thought levels could be lowered
- Women feel more unsafe compared to men; although the reasons were lack of people and time of the day
- None of them associated light levels with safety; but felt it was about people and not light.

#### A.4 LIGHTING SITUATION WITHOUT ANY PRESENCE OF PEOPLE



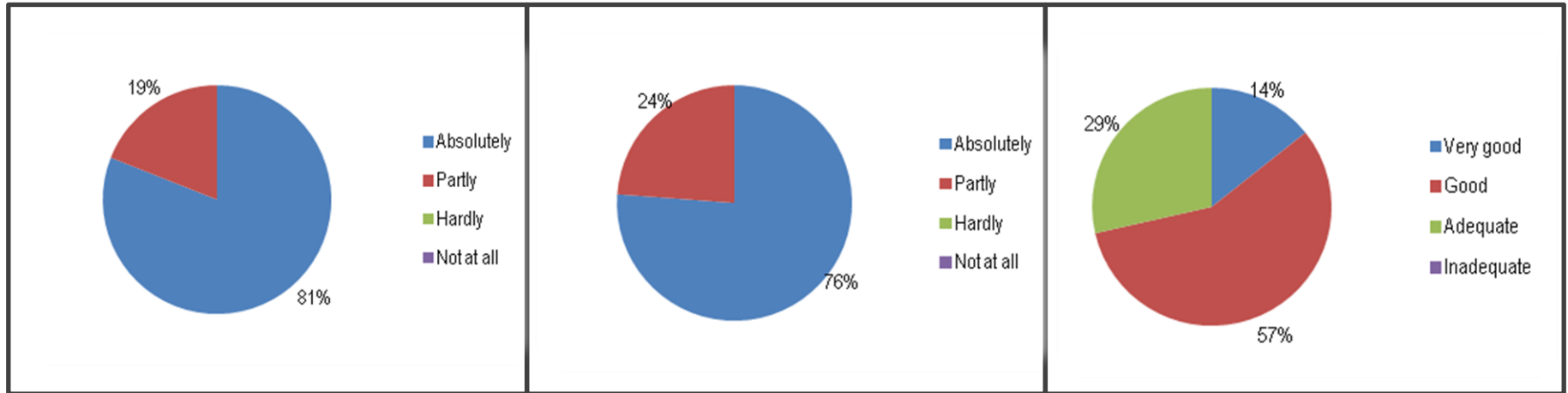
#### A.5 LIGHTING SITUATION WITH PRESENCE OF PEOPLE



#### SCENARIO #2

- Low power level – 5
- High power level – 8
- Timer settings – 120 seconds
- No. of poles – All
- End 3 poles of the stretch at level – 7 all the time

## (A) USER RESPONSES EVALUATION – SCENARIO #2



SAFETY

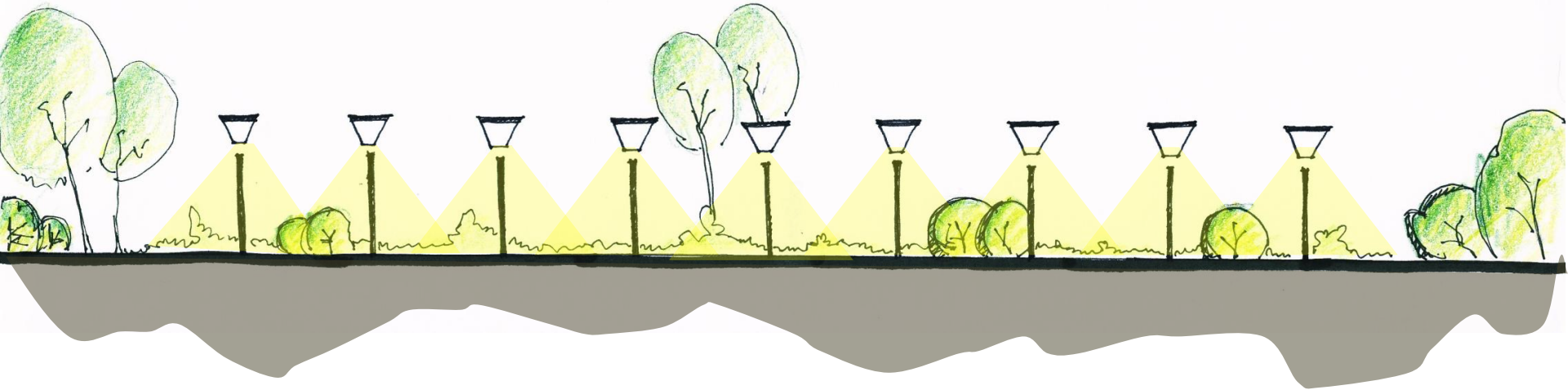
VISUAL COMFORTABILITY

PERCEPTION

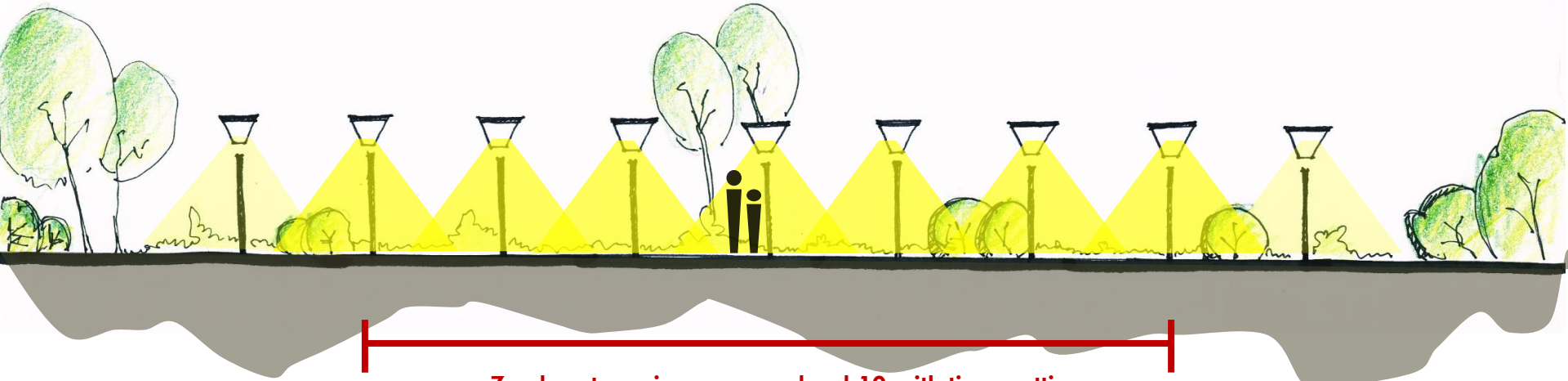
### SCENARIO #2

- Same responses like earlier cases, indicating that people didn't perceive the difference in light levels.
- Lighting of vertical planes is as important as horizontal planes for good surrounding/ ambient light.
- Trees and foliage should be lit in order to make people feel secure in the space, free from any attack from unlit spaces
- One of the user suggested the experiment to be carried out in winter time, when the surroundings are totally different.

## A.6 LIGHTING SITUATION WITHOUT ANY PRESENCE OF PEOPLE



## A.7 LIGHTING SITUATION WITH PRESENCE OF PEOPLE



### SCENARIO #3

- Low power level – 5
- High power level – 10

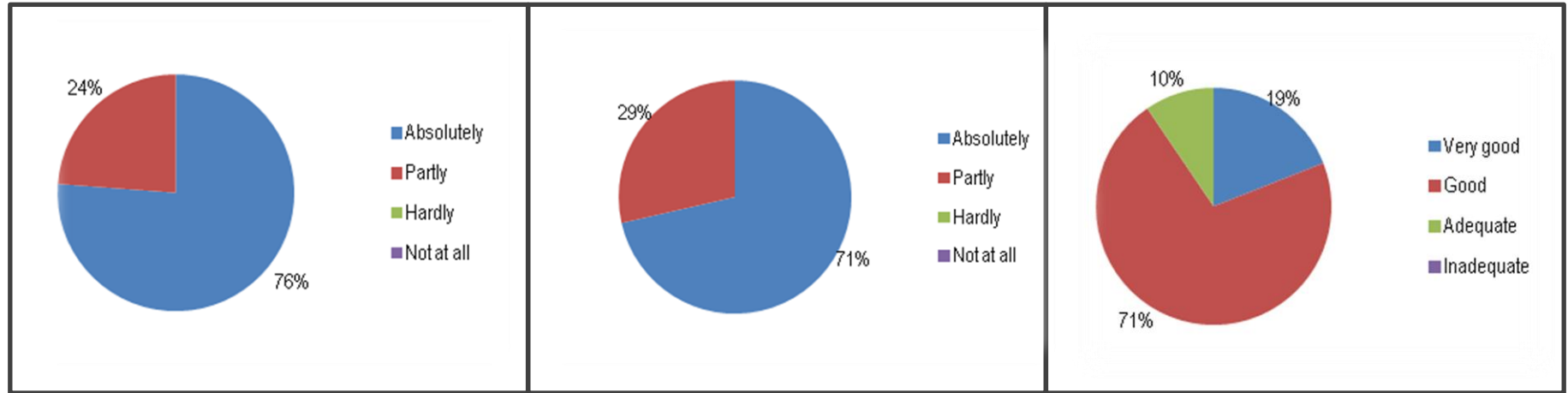
**7 poles at maximum power level-10 with timer settings at 120 seconds**

**(3 poles ahead of the current position of the user + pole at current position of the user + 3 poles behind the current position of the user)**

- Timer settings – 120 seconds
- No. of poles – 7 (3+1+3)
- End 3 poles of the stretch at level – 7 all the time



## (A) USER RESPONSES EVALUATION – SCENARIO #3



SAFETY

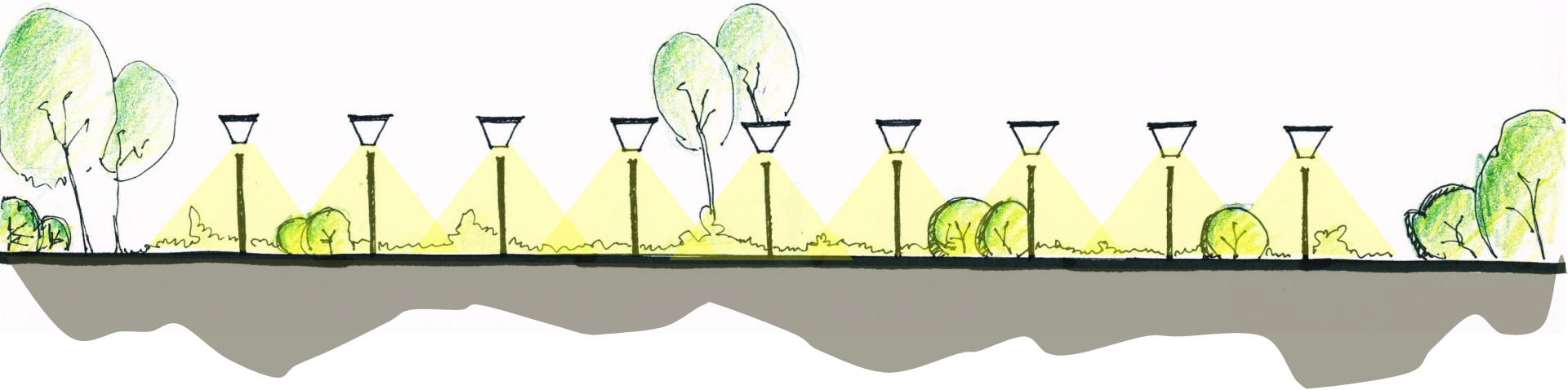
VISUAL COMFORTABILITY

PERCEPTION

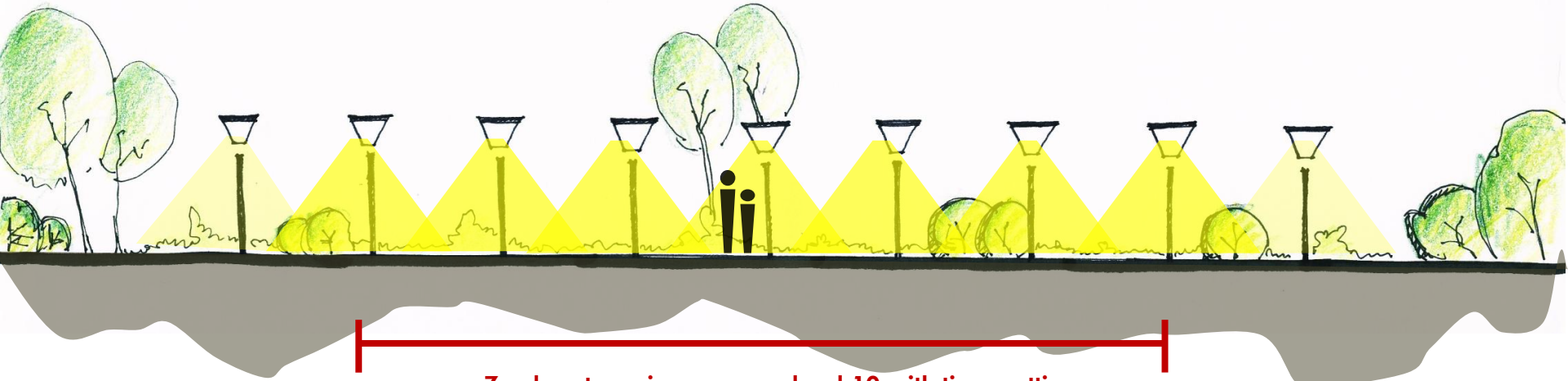
### SCENARIO #3

- Light levels were perceived to be good; transition from low to high level was gradual and smooth causing no feeling of uncomfotability.
- Cultural backgrounds play an important role in the perception of safety.
- Trees and foliage should be lit in order to make people feel secure in the space, free from any attack from unlit spaces
- People very positive towards the idea of energy efficient lighting
- Color of light was good making it easier to perceive the actual colours and surroundings on the site

## A.8 LIGHTING SITUATION WITHOUT ANY PRESENCE OF PEOPLE



## A.9 LIGHTING SITUATION WITH PRESENCE OF PEOPLE



### SCENARIO #4

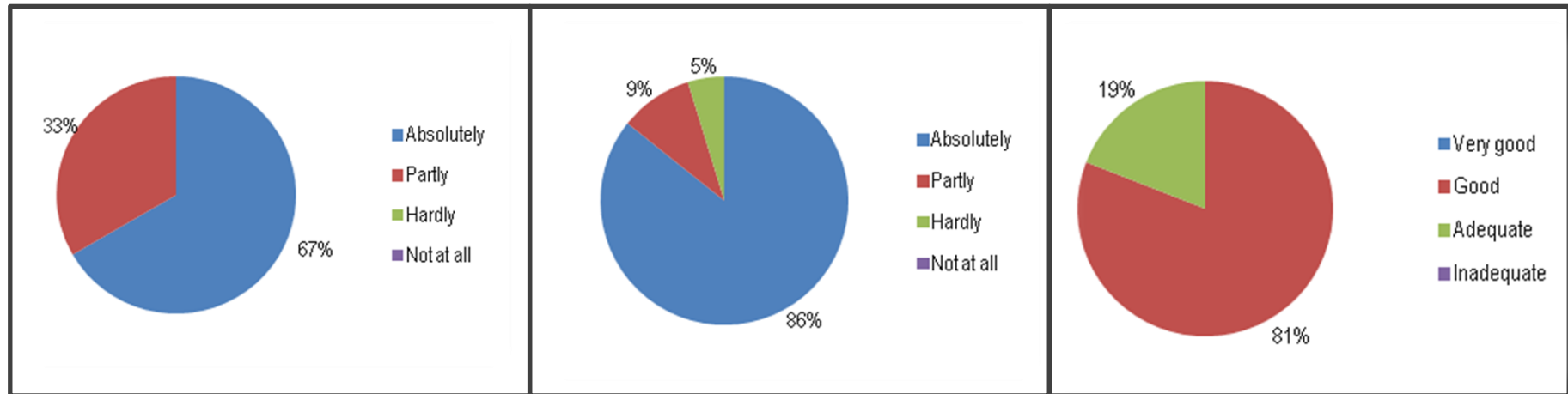
- Low power level – 5
- High power level – 10

**7 poles at maximum power level-10 with timer settings at 60 seconds**

**(3 poles ahead of the current position of the user + pole at current position of the user + 3 poles behind the current position of the user)**

- Timer settings – 60 seconds
- No. of poles – 7 (3+1+3)
- End 3 poles of the stretch at level – 7 all the time

## (A) USER RESPONSES EVALUATION – SCENARIO #4



SAFETY

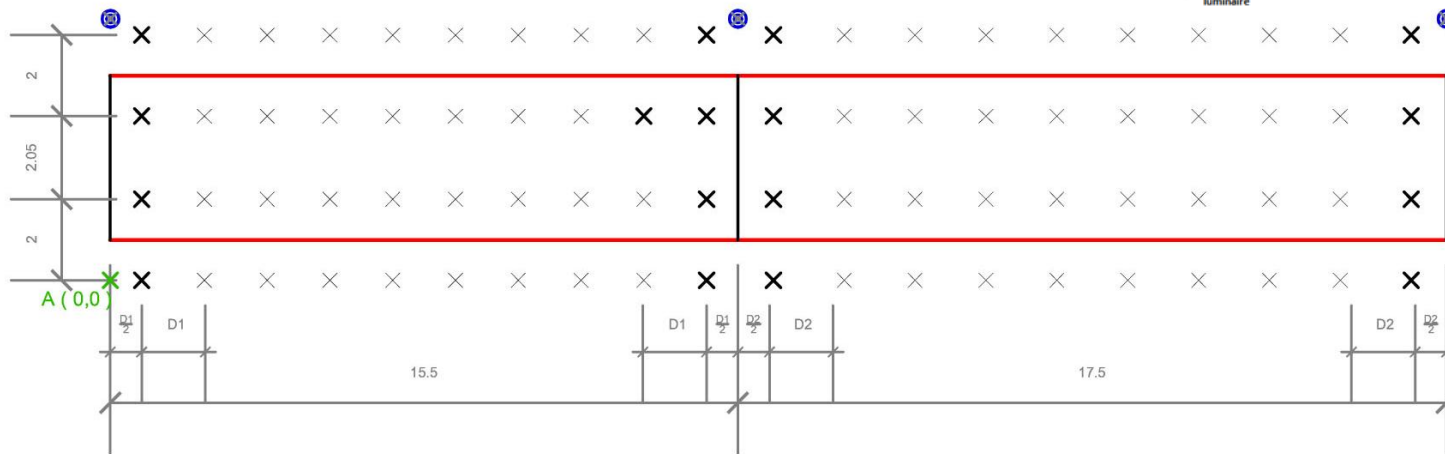
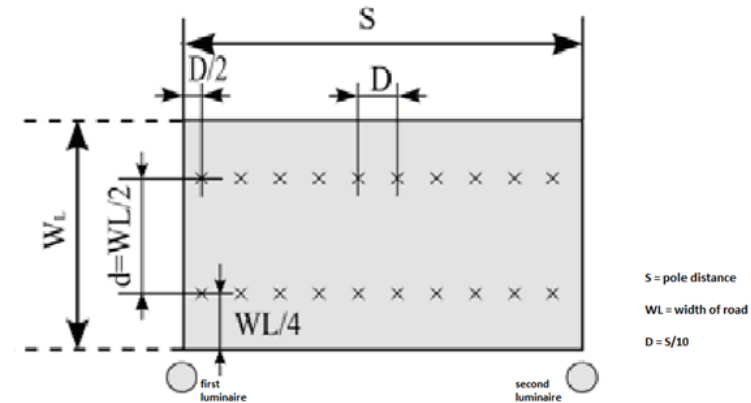
VISUAL COMFORTABILITY

PERCEPTION

### SCENARIO #4

- Light levels were perceived to be good; transition from low to high level was gradual and smooth causing no feeling of uncomfortability.
- Few thought the distribution of light was uneven due to inconsistent distance between light poles.
- Busy hours feel safe, late hours arise the feeling of insecurity because of lack of people.
- People very positive towards the idea of energy efficient lighting; especially with the growing concern of light pollution

## (B) LUX LEVEL CALCULATIONS



⊙ LIGHT POLES

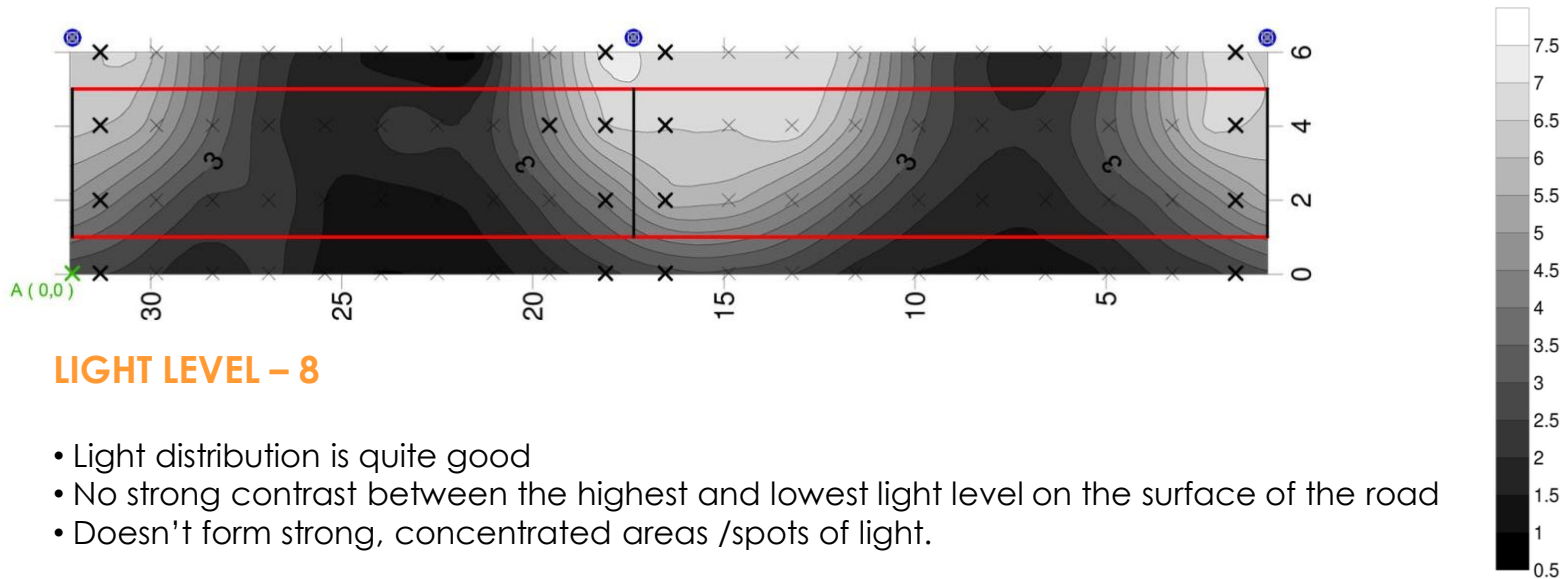
A(0,0) ORIGIN

— LIMITS OF THE ROAD

- On the examined part of the road,

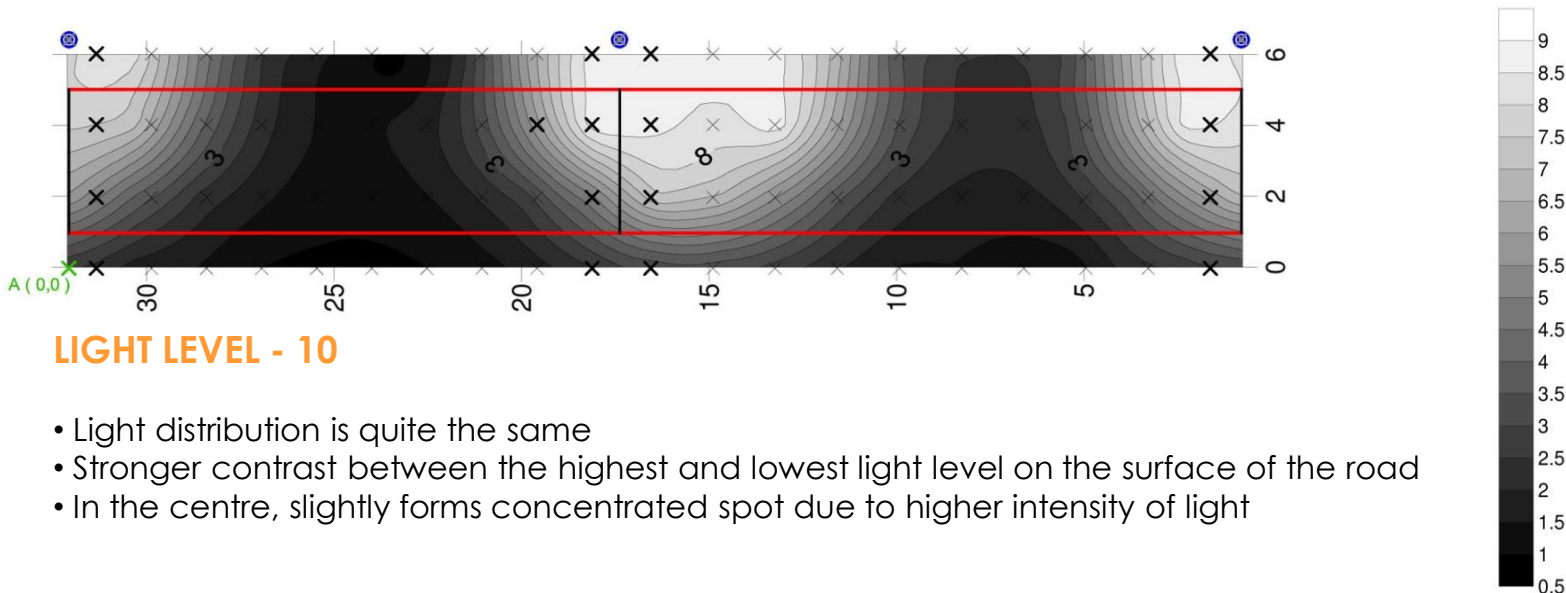
$$S_1 = 15.5\text{m}, W_L = 4\text{m}, D = S_1/10 = 15.5/10 = 1.55\text{m}$$

$$S_2 = 17.5\text{m}, W_L = 4\text{m}, D = S_2/10 = 17.5/10 = 1.75\text{m}$$



### LIGHT LEVEL - 8

- Light distribution is quite good
- No strong contrast between the highest and lowest light level on the surface of the road
- Doesn't form strong, concentrated areas /spots of light.



### LIGHT LEVEL - 10


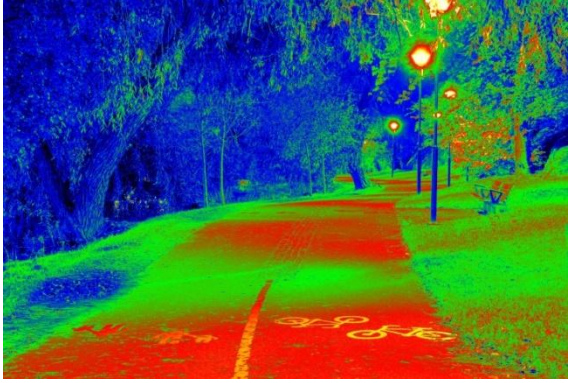

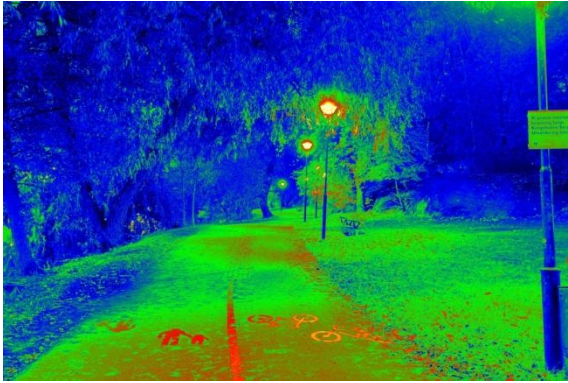
- Light distribution is quite the same
- Stronger contrast between the highest and lowest light level on the surface of the road
- In the centre, slightly forms concentrated spot due to higher intensity of light

## (C) LUMINANCE DATA


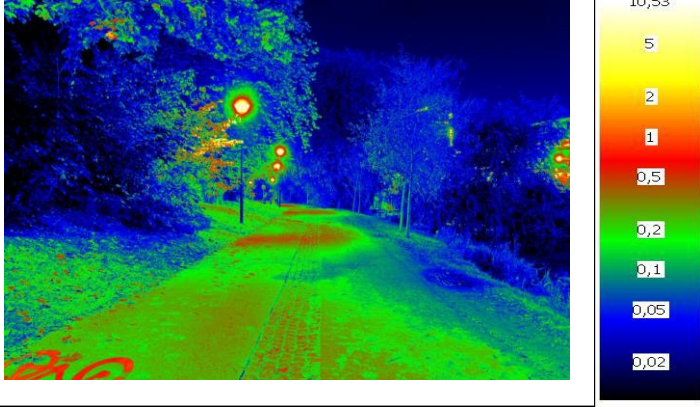




- Capture photographs to understand the perception of the lighting from the human perspective in the space

# VIEW 1


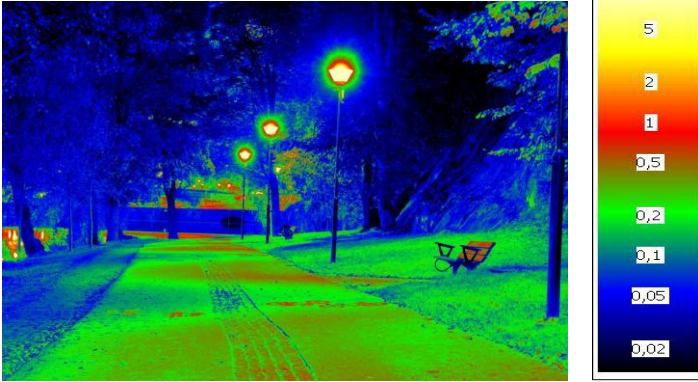

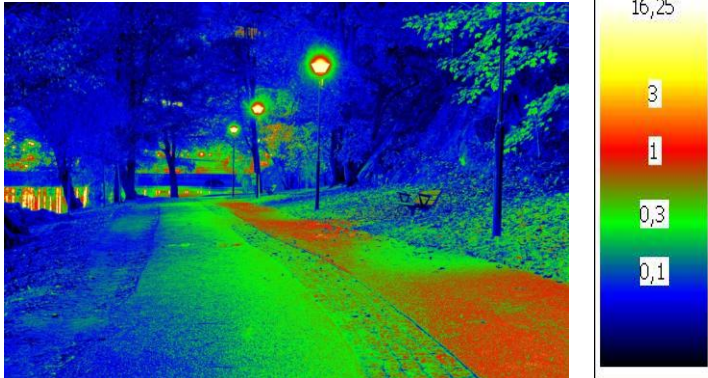
PHOTOGRAPH	LUMINANCE PICTURE WITH COLOUR SCALE	OBSERVATIONS
<p><b>MAXIMUM LIGHT LEVEL - 10</b></p> 	 <p>L [ cd/m<sup>2</sup> ]</p> <p>7,192 5 2 1 0,5 0,2 0,1 0,05 0,02 0,01</p>	<ul style="list-style-type: none"> <li>• The light levels seem to be balanced and not very bright in case of the light level 8</li> <li>• Light level 10 is perceived to be brighter.</li> <li>• Light level – 8 photograph has a uniform distribution of light in the picture where as light level – 10 picture looks very bright on the horizontal surface of the road.</li> </ul>
<p><b>MAXIMUM LIGHT LEVEL - 8</b></p> 	 <p>L [ cd/m<sup>2</sup> ]</p> <p>7,9 5 2 1 0,5 0,2 0,1 0,05 0,02</p>	<ul style="list-style-type: none"> <li>• Color scales comparison</li> </ul>

## VIEW 2

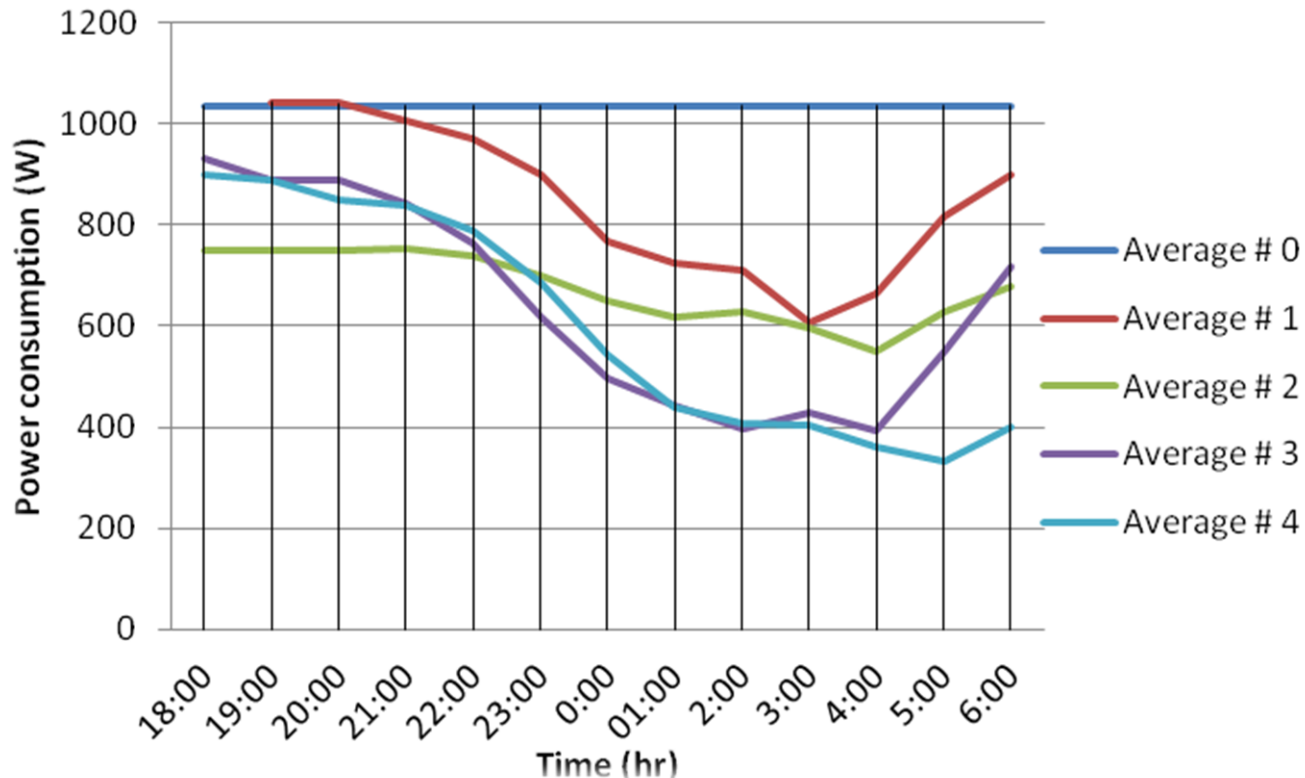
PHOTOGRAPH	LUMINANCE PICTURE WITH COLOUR SCALE	OBSERVATIONS
<p>MAXIMUM LIGHT LEVEL - 10</p> 		<ul style="list-style-type: none"> <li>The light levels seem to be balanced and not very bright in case of the light level 8</li> <li>Light level 10 is perceived to be brighter.</li> <li>Both the pictures photograph have uniform distribution of light in the pictures – shown in colour scale where both have greenish band colours.</li> </ul>
<p>MAXIMUM LIGHT LEVEL - 8</p> 		<ul style="list-style-type: none"> <li>Surroundings make a difference – both the pictures give quite the same luminance impression even though the light levels are higher in the first case.</li> </ul>



# Comparisons between dimmed background and maximum light level at the current position versus level-10 along the whole installation

PHOTOGRAPH	LUMINANCE PICTURE WITH COLOUR SCALE	OBSERVATIONS
<p><b>LIGHT LEVEL – 10</b> along the whole installation</p> 		<ul style="list-style-type: none"> <li>• One cannot easily perceive the difference between both the pictures</li> <li>• Weather (rainy) is affecting the reflectance and hence the luminance in the picture.</li> </ul>
<p><b>LEVEL – 10</b> (3 poles ahead of the current position of the user) and <b>LEVEL – 5</b> to which rest of the installation is dimmed.</p> 		<ul style="list-style-type: none"> <li>• Surrounding light interference makes it difficult to notice any difference in the two situations.</li> <li>• Isolated area without interfering surrounding light might have made the difference in light levels a bit more obvious.</li> </ul>

## (D) ENERGY CONSUMPTION CALCULATIONS



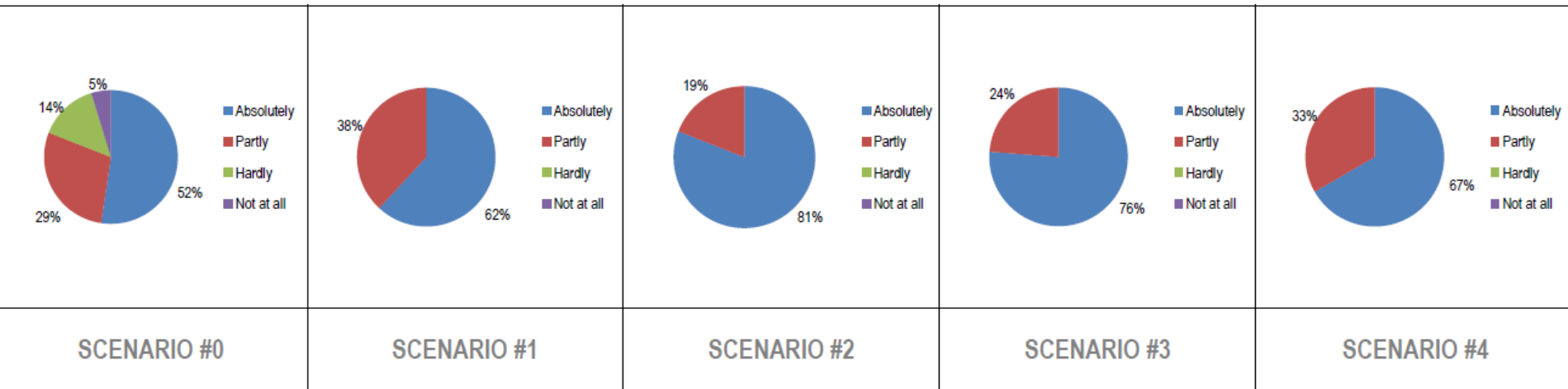
Graph comparing the average power consumption levels for all the scenarios

**SCENARIO #0 > SCENARIO #1 > SCENARIO #2 > SCENARIO #3 > SCENARIO #4**  
**1035 W > 845.55 W > 676.15 W > 642.82 W > 603.07 W**

Highest power consumption values to lowest power consumption values.

## 4 EVALUATION BY COMPARISONS AMONG SCENARIOS

### • SAFETY



### Q5. "Do you feel safe while walking on this road?"

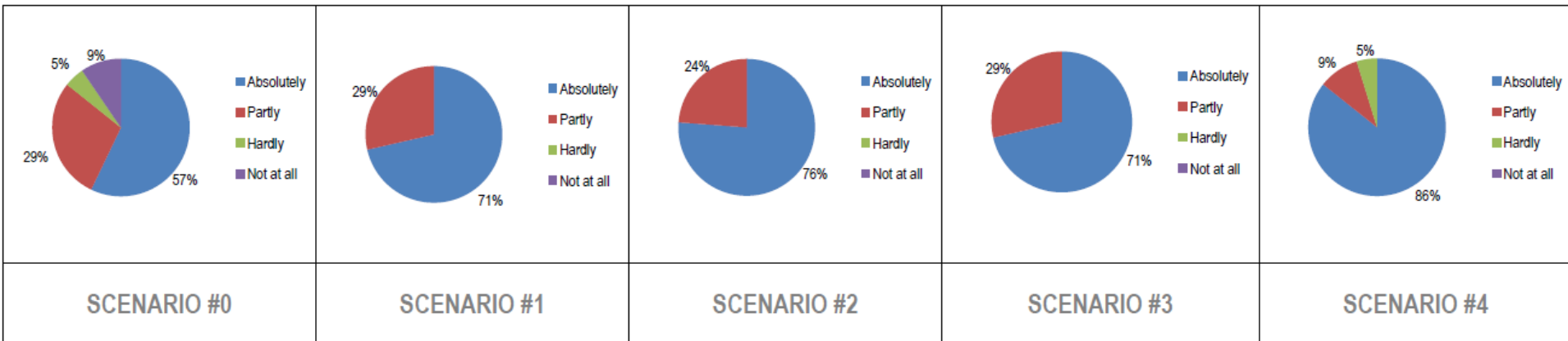
- The scenarios can be arranged starting from the most safe to the least safe scenario as follows:

**SCENARIO#2 > SCENARIO #3 > SCENARIO #4 > SCENARIO #1 > SCENARIO #0**

**Decreasing level of safeness**



## • VISUAL COMFORTABILITY



**Q. 6 “Is the light here enough for what you need to see?”**

- The scenarios can be arranged starting from most visually comfortable to least as follows:

**SCENARIO#4 > SCENARIO #2 > SCENARIO #3 = SCENARIO #1 > SCENARIO #0**

**Decreasing level of visual comfortability**



• PERCEPTION

(Very good +Good)% = 57%	(Very good +Good)% =95%	(Very good +Good)% =71%	(Very good +Good)% =90%	(Very good +Good)% =81%
SCENARIO #0	SCENARIO #1	SCENARIO #2	SCENARIO #3	SCENARIO #4

**Q.7 “How do you judge the lighting situation?”**

•The scenarios can be arranged from most to least preferred scenario in terms of perception as follows:

**SCENARIO#1 > SCENARIO #3 > SCENARIO #4 > SCENARIO #2 > SCENARIO #0**

**Decreasing level of good perception**

## RANKING\* AMONG ALL SCENARIOS (summing up all the aspects)

SCENARIO	USER RESPONSES			ENERGY VALUES	RESULT
	SAFETY	VISUAL COMFORT♦	PERCEPTION	ENERGY CONSUMPTION <i>(Based on the average values for the common days)</i>	
#0	1	1	1	1	4
#1	2	2	5	2	11
#2	5	3	2	3	13
#3	4	2	4	4	14
#4	3	4	3	5	15

1 = least preferred; 5 = most preferred

In the column of 'VISUAL COMFORT♦', scenario #1 and #3 are ranked the same as they gave same results .

## 5 RESULTS

- Scenario #4 is the most preferred scenario , closely followed by scenario #3.
- Scenario #0 without the use of any lighting control system proved to be the least preferred scenario.
- Based on both VISUAL and TECHNICAL evaluation, the order of preference for scenarios is as follows:

**SCENARIO#0 < SCENARIO #1 < SCENARIO #2 < SCENARIO #3 < SCENARIO #4**

**Increasing order of preference**



### PROJECT GOALS WERE ACHIEVED

- *'While there is a risk that controlling the environment in itself defeats the purpose of creating a secure and transparent environment, project will examine how governance should be designed so as not to jeopardize the safety of users comfort.'*
- *'Technology assessment (energy savings, reliability, etc.) will be related to how users perceive visual quality, safety and security.'*
- *'For the pilot project involving lighting control, the idea is to provide a saving potential between 40-60% of energy use, compared with the old traditional system (high- pressure sodium lamps). By installing an intelligent lighting control that reduces lighting levels at night, is estimated to reduce more than 30% for the remaining energy.'*

## ENERGY SAVINGS :

SCENARIO #1 – 18.4%

SCENARIO #2 – 34.7%

SCENARIO #3 - 37.9%

SCENARIO #4 – 41.8%

•‘The evaluation will lead to strategies (possibly multiple) for illumination of the path that meets the balanced energy-efficiency, economy and comfort of road users (security, safety, visual quality).’



## 7 CONCLUSIONS

- **ANSWERS TO THE MAIN QUESTIONS :**

- The presence control system in outdoor lighting installation could work well with the users without compromising on their road user comfort.
- People positively embrace the idea of energy- efficient solutions.

- **SITE CONTEXTUAL POINTS :**

- Dark surfaces and closed boundaries create feeling of insecurity and vulnerability
- Colour of the surfaces affect the perception of the lighting and the space
- Surroundings and external light influences the perception
- Lighting of the vertical surfaces is equally important as the lighting on the horizontal surface of the road

- **SAFETY :**

- People associate safety with light levels, although the reality might be different.
- Good view of the overall surroundings is necessary to feel safe
- Easy navigation and orientation in a space makes one feel secure
- Cultural background of the people affects the perception of safety.

- Men generally feel safer than women in the environment – But just not due to lighting but lack of people and time of the day
- Middle aged groups have mixed response towards safety; youngsters are the most vulnerable and oldest feel the most safe.

#### • **VISUAL COMFORTABILITY :**

- The adaption of the eye from 50% light output to 100% seems comfortable.
- Very high light levels are not preferred by the users.
- Good amount of surrounding light required for good vision
- Oldest age group were the most satisfied lot.

#### • **PERCEPTION :**

- The surrounding features can affect the perception of the space (colour of surroundings; physical features affecting the field of vision)
- Materials and changing weather conditions affect the perception of luminance levels in the space.

- Lastly, can we dream of a future in sustainable lighting using lighting controls? – Yes!
- The research shows it has a lot of potential to be explored.
- With more studies, it can be widely implemented.
- Hoping for a smart and sustainable future!

**THANK YOU!**