ENVISIONING THE FUTURE OF PUBLIC LIGHTING THROUGH UPCOMING TECHNOLOGIES BY CITIZEN-CENTERED DESIGN

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Tiivistelmä

Katuvalaistus muodostaa tärkeän osan julkista infrastuktuuria maailmanlaajuisesti. Katuvalot ovat pitkään pysyneet samankaltaisina toiminnoiltaan. Mukautuva valaistus on nykyään laajamittaisesti testattu ja käytetty teknologia älykkäissä valaistusjärjestelmissä, joka on sensoreja käyttävä teknologia, jossa LED valoja himmennetään ja kirkastetaan kadulla tapahtuvan liikenteen tai kontekstin mukaan. Teknologian hyötyjä ovat muun muassa energian kulutuksen ja valosaasteen vähentäminen ja pienemmät vaikutukset eläinten ja kasvien vuorokausirytmeihin. Tällä uudella teknologialla ja sen käyttöönotolla on myös haasteensa. Teknologian vaikutuksien testaaminen suurissa kaupungeissa eri konteksteissaan on monimutkaista, vaikka urbaanit teknologiat tulevat vaikuttamaan suoraan ihmisten päivittäiseen elämään.

Pyrin mahdollistamaan asukkaiden osallistamisen tulevaisuuden katuvalaistuksen visioinnissa. Myös muilla tulevaisuuden teknologioilla on vaikutusta tulevaisuuden katuvalaistukseen. Tutkimuksen laajuuden rajoissa otettiin huomioon kolme muuta tulevaisuuden teknologiaa. Tutkin tulevaisuuden älykästä katuvalaistusta itseohjautuvien autojen, valoa käyttävän kommunikaatioteknologian Li-Fi:n ja energia varastojen kontekstissa. Itseohjautuvat autot voivat muuttaa käsitystä siitä, miten näemme valaistuksen roolin teillä. Autot voisivat kommunikoida toistensa kanssa Li-Fi:n avulla saaden sensoreiden tuottamaa dataa ympäristöstään. Kotitalouksien akut voisivat olla yhdistettynä katuvalaistusverkkoon ja kaupungit voisivat vuokrata varastoja tai ostaa energiaa, joka on tuotettu yksityisesti. Näiden tulevaisuuden teknologioiden avulla voidaan ennakoida katuvalaistuksen roolin muutosta. Pyrin korostamaan tätä heijastavaa suhdetta muuttuvien urbaanien teknologioiden välillä ja esittämään potentiaalin asukkaiden osallistamisessa kaupunkiympäristöä muodostaessa. Osallistin kaupungin toimihenkilöitä käyttäen muotoilumenetelmiä luoden tulevaisuuden visioita älykkäästä valaistuksesta ja tämän vuorovaikutuksesta kolmen tulevaisuuden teknologian välillä. Katuvalaistuksen toimintojen visiointiin käytettiin asukkaiden kanssa osallistavia muotoilumenetelmiä.

Avainsanat katuvalaistus, älykäs valaistus, kaupunkisuunnittelu

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Abstract

Outdoor lighting forms an essential component of public infrastructure in global urban context. The functions of street lighting have been the same for a long time. Currently, adaptive lighting is used within intelligent lighting systems that are tested for wide deployment. Adaptive lighting is a sensor-based system that uses LED technology to dim and brighten lighting on the streets depending on its context and movement on the streets. The benefits of the technology include, for example, the reduction of energy consumption, light pollution and disturbance of circadian rhythms of animals and plants. This new technology and its deployment have its concerns. Testing the impact of such a public lighting within the major cities in multiple contexts is complex. While urban technologies affect the everyday lives of people, involving them in shaping such a future public infrastructure and widening its application through participation is far from simple.

Within the scope of my research, I wish to address enabling citizens' participation in the visioning of future technologies that may have an impact on public lighting. Therefore, I chose to frame adaptive lighting of smart cities in the context of three future technologies, of autonomous cars, Li-Fi and battery storage. Autonomous cars could change the way we see the role of the public lighting of roads. With Li-Fi, cars could communicate with street lights accessing sensor data from the environment. Household batteries could be connected to street lighting grid and cities could rent storage or buy energy produced by private infrastructure. With these upcoming technologies, changes in the role of outdoor public lighting can be anticipated. I wish to highlight this reflexive relation between changing urban technologies and present a potential for citizen participation in shaping their urban environments. By using design procedures, I engaged with city officials and citizens in creating future urban visions for adaptive lighting and its interaction with three future technologies.

Keywords katuvalaistus, älykäs valaistus, kaupunkisuunnittelu

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This research was carried out in a Light energy project, which is a multi-disciplinary research project belonging to the Aalto University Energy Efficiency Research Program. The research was carried out in the Department of Design and Arts, Aalto University and focuses on user-centric design approaches while other studies of the project concentrated on the technical side of lighting and energy efficient energy use.
The starting point of the research was designing approaches in adaptive lighting.

Thesis Supervisor for this work was Karthikeya Acharya and Advisor was professor Turkka Keinonen from Aalto University.

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1. INTRODUCTION

The objective of this thesis is to develop a vision and service around intelligent street lighting for framework of Finland. To accomplish the vision, the thesis studies citizens needs on street lighting based on the three associated technologies, namely autonomous cars, visible light communications, and energy storages. Also, the thesis develops an approach for involving citizens in the design process with a collaborative service that can shape street lighting in the future.

New technologies have been recently introduced to reduce existing problems. Adaptive lighting was invented to reduce energy consumption and light pollution. The technology uses sensors to detect movement around them and dims lighting levels when there is no movement around a lighting pole. However, new technologies often create new challenges and problems. Issues ranging from user needs to the functionality of the whole system need to be studied to ensure safety and orientation in the city for citizens. Designers are trained to solve problems from user-centric viewpoint, instead of just inventing new technologies. The properties of adaptive lighting, such as acceptable dimming level (Viliunas et al. 2014) and the effects of dimming on the feeling of safety (Haans & de Kort, 2012), have been studied in different universities as well with the tests of technology providers and developers.

There are opportunities to make cities function better in this stage of introduction of new technologies. A city becomes more functional as the infrastructure of street lighting is developed to be intelligent.

Future technologies and concepts, such as the Internet of things and the smart city, can potentially benefit everyone in the city but the specific means to accomplish this remain unclear. Developing a technology does not happen without a context or users. Street lighting have not yet been actively designed collaboratively with citizens. Technologies are developing fast and open possibilities for exciting and meaningful functions but citizens needs for new technologies are not always obvious. Therefore, this thesis aims to involve citizens in imagination of future street lighting functions, which enables building a vision of future intelligent street lighting and a service, which would help in designing better cities and developing meaningful human environments. In this thesis, the process of achieving these goals are shown. In the chapter Street lighting then and now the history, current situation and a few future technologies of street lighting are studied. The chapter Technologies of the future covers upcoming technologies related to urban context, namely smart city, Internet of things, autonomous cars, Li-Fi and energy storages. The start of productive work of the thesis is presented in the chapter Preliminary research which introduces the research to discussed in chapter User research¬. in this part, the main user research is presented. The chapter Defining the output synthesizes the findings of research which will justify the decisions that led to the chapter Design vision.

1.1.CITY DESIGN

It is difficult to imagine the future functions of intelligent lighting systems without defining a broader image of the city and its inhabitants. Technologies exist, and they are developed, but the implementation of new technologies is not always clear. To obtain meaningful solutions, citizens of today need to be involved in the development of the products and services. In design practice, a development process in which citizens are in the center is called user-centered design (Mattelmäki 2008), which refers to an ideology and methods in design practices where users of product, service or systems are in the focus by involving them in process. In a city context, a similar practice is called urban design. The methods in them are quite similar, however the number of target group is bigger. The terms urban design, also known as city design, refer to a process of shaping cities by focusing on streets and public places, with the objective of making areas functional, attractive and sustainable.

A United States based company, Citysmart, shows a case example of a successful urban design. The company whose mission is to solve problems by connecting them with new ideas through open challenges to entrepreneurs and citizens serves an example the benefits of urban design. Sascha Haselmayer introduces two different solutions of helping blind people in Minnesota and Stockholm in his speech “Let’s spend city money on empathy” given in TEDxHamburg. The state of Minnesota created talking traffic lights and Stockholm created a small navigation aid that the users can carry around. The results showed that the users in Stockholm felt 90 % less disabled, unlike the users in Minnesota. The main difference between the two processes was that in Minnesota it was the city planners who defined what the tool should do, whereas in Stockholm the city planners talked with people with visual impairment, prioritizing the user. This process did not cost any extra money for the city, but the solution was drastically better (Citysmart, 2014).

Recently the benefits of the urban design have been acknowledged, and the city of Helsinki aspires to make future urban design more participatory. Anne Stenros, the first head of design of Helsinki, stated on a television interview that Helsinki strives to improve the role of citizen participation since they are the experts in their living environment. Apart from that, having different opinions on the same matter has also given better results (YLE, 2011). Interesting urban design projects have been done in Helsinki, which has made the approach more familiar to the city. A Design driven city project “Toimiva kaupunki” was a two-year project started in Helsinki in 2012. The project promoted the use of design in urban environments, making the cities better, more easygoing and more functional. One of the projects outcomes were ten theses, which explain why Design driven city believes that a great city is built together with citizens. The points of theses are listed in following page. The theses presented above underline the importance of collaboration. City, citizens or designers cannot provide great solutions without working together. Everyone has an important role in the process. Many cities have recently hired more designers, especially because of increasing education in service design, which helps to see services from user-centric viewpoints and with creative solutions. These examples also show the growing role of designers in urban environments. Therefore, in this thesis participation methods are studied from a designer’s point of view and role in a city context.

Ten theses by Toimiva kaupunki

1. Cities should be user-friendly
2. Cities need design to prosper
3. Design creates better services for citizens
4. Co-designing means engaging citizens
5. Cities are entities
6. Cities need multi-disciplinary collaboration and know-how
7. Design saves money and creates less service needs
8. Cities can also be developed through experiments
9. Future services are for citizens, not for cities
10 A design-driven city is a good city

Traditional way of thinking the city as a elements of infrastructure, such as the streets, architecture and planning is challenged with a thought, that the city is done by the people and the organizations of the people. City is formed by what the people do in it. New ways of design qualifies the city more and more as a social innovation avenue, where the innovations of the surroundings are generated by the citizens themselves (Manzini 2009). In order to create user-friendly cities, people’s actions and perspectives need to be understood, which can be obtained through user-centered design methods. Collaborative and user-friendly design tools provide ways for citizens to shape their environments independently. Citizens can be engaged in the decision-making process to change their surroundings and can help to lower the barrier to use new services. User friendliness also helps the decision makers understand the citizens better and implement user information directly. Overall, user-centered design helps to build a deeper understanding of users, producing new information and points of views. Design practices can also cut costs by searching for smarter ways of producing public services with a better understanding of customers.

Design practice is all about problem-solving. More complex systems and continuous growth will cause new problems in future cities. The problems can be solved with creative problem solving and design thinking. Design methods help to pinpoint new ways of building better future cities by focusing on inhabitants. In user-centered design, the user is always at the core of the process and addresses the objectives of the service providers. Since cities offer a variety of services, one benefit of design is that it offers an alternative way of seeing public services. Problems can be solved by questioning the current ways of doing with an open attitude to controversial solutions. At its best, design could make everyday life of inhabitants easier and more enjoyable. Designers are trained to look everything in the big picture. By understanding the citizens, providers, and technologies, designers can see the problems in a larger perspective. Designers can understand the user experience and provide creative solutions. However, they cannot solve urban problems alone. Experts, city planners, designers, and citizens can enhance multi-disciplinary collaboration in various ways.

The term citizen centered design, which I use in this thesis, underlines the focus on citizens as an important group in city and its development. Instead of using more established term user-centered design, I want to differentiate citizens from users since everyone in the city are users of street lighting. One point is that one individual can represent many user groups of street lighting even during one day. For example, the needs of a pedestrian and a car driver are different. Therefore, the needs of an individual might change during a day as well. Only users that have power to have an impact on future of street lighting today are normally are city officials and developers of street lighting. Therefore, the term citizen centered design reflects on the philosophy on the user-centered design and urban design as a combination of them both.

1.2.RESEARCH QUESTIONS

Urban design is used as a guideline of the process and research of collaborative needfinding of intelligent lighting. Street lights are experienced by all citizens and the additional functions could be planned by the designer alone. Designers have their opinions on services and. However they are rarely similar to those of target group (Hyysalo 2009). User-centered design methods should be used to design something meaningful for all citizens.

Due to the geographic location I facilitated my research in capital area of Finland, where the availability of daylight varies between 6 and 19 hours, depending on the time of the year. This makes capital area interesting environment for street lighting research compared to more southern cities in Europe. Long, dark winters increase the need for artificial lighting. During the progress, Helsinki was chosen to be the main location of research and a case example of decision making in street lighting. With these elements in mind, I present my two research questions;

How can citizens be involved in planning the city's future infrastructure?

Since the target group is everyone in the city, they need to be heard to get various opinions. Based on desk research done in this research, it is safe to say that intelligent lighting is not planned collaboratively with inhabitants. Innovations do not always start from the companies' product development departments. Not finding out how users can support the development work of a product is wasting an important resource of know-how (Hyysalo 2009). Instead of designing finished lighting systems, this thesis concentrates on ideation and early development of future street lighting services. Since the adaptive and intelligent street light technologies are novel, there is very little experience in them. Urban design requires citizens' engagement to work. Nevertheless, collaborative methods of the future imagination of the technologies are complex. The following research studies the methods of citizen participation in decision-making process and development of street lighting.

Collaborative design methodology, where users are taken part of the ideation and development, provides ways to involve citizens. The challenge is to research how the city is different environment for the collaboration with the citizens with the technology that has not been implemented yet.

What are the needs of the citizens for future intelligent lighting?

At the moment, adaptive lighting is not very widely researched and intelligent lighting even less. Since there are only few testing environments with adaptive lighting in capital area, the citizens have little possibility to react and give feedback to the city. This progress is slow, and the lack of insights do not spur acceptance of new technologies. The research in this thesis can function as a direction for the development of intelligent street lighting systems. The second question discusses what technologies make sense for citizens and which should therefore be focused on. The question aims to map the citizens needs of possible future technologies of cities.

1.3.PROCESS

It is essential to make the citizens voice heard in urban design, especially in the context of rapidly evolving future technologies. Towards such a need the project takes a path through design. My approach to design research is both constructive (Koskinen et.al, 2011) and user-centered (Keinonen & Jääksö 2004). In the process, I created design concepts with people and document them or hand over prototypes to them and follow their responses in interaction as inquiry.
My inquiry began with desk research on the topic of public lighting to broaden my understanding of public lighting and the need for viewing it about its context with other technologies. The initial design concepts were created to initiate a discussion about intelligent lighting systems with city officials. The analysis from these sessions informed further design research with citizens as users of future technologies. The analysis resulted in narrowing three upcoming technologies and identifying the five most relevant user groups.
The analysis from this phase led to generating a Technology-User Matrix. With this Matrix, I identified the five most relevant user groups, their relationship to the upcoming technologies and their contexts. For these groups, I then carried out three design based procedures; a user based scenario building session, situated testing of an application mock-up and a design workshop that made the participants imagine urban public outdoor lighting and its interaction with upcoming technologies. A further analysis of these design procedures of revealed the possible characteristics when public outdoor lighting interacts with three upcoming technologies which were taken into design visions.

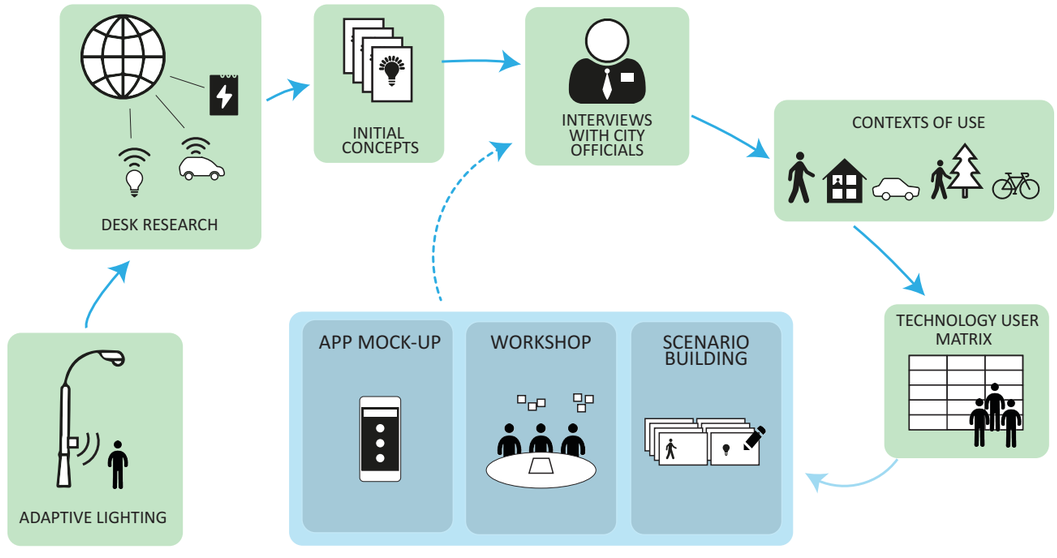


Figure 1. Process visualized

2. STREET LIGHTING THEN AND NOW

In this chapter, I will explain the brief history of the technological progress of street lighting throughout history and concepts and definitions of street lighting. The history of street lighting helps to understand why and how street lights are like they are today. New technologies paint a picture what alternative future roles and functions lighting might have.

2.1. HISTORY OF STREET LIGHTING

Street lighting is almost taken for granted by modern urban citizens of cities. Historically outdoor lighting was introduced as a way to reduce crime in the streets and make citizens feel safer during dark hours. Lighting supports commercial and leisure activities at nighttime and gives freedom to go out at night without fear of attacks or accidents caused by poor visibility. (Haans & De Kort, 2012). Nowadays the focus of outdoor lighting is mostly in reducing the number of car accidents. Proper lighting also benefits drivers by offering visual comfort and helps to detect other road users (Raynham, 2004). Another focus is allowing pedestrians to see obstacles, orientating and seeing faces of other pedestrians (Boyce 2014). Lighting works as signage for orientation in the city when landmarks such as buildings and trees are illuminated. Additionally, lighting makes urban environments aesthetically more pleasing and highlights the characteristics of cities.

The first type of organized street lighting was operated in the year 1417 by the mayor of London, who ordered that all homes had to have lanterns outdoors after nightfall during the winter months. Later, in 1802, coal-fueled gas lights were installed more widely in the streets of London. In 1816 Baltimore became the first city in the United States to install gas streetlights. Paris followed right after by installing gas lamps in 1820 and also became the first city in the world with electric streetlights in 1878. Low-pressure sodium lamps that are still used today were introduced in Europe in 1930 (EATON, 2015). Similar technologies, such as metal-halide and mercury-vapor lights, were introduced later and those have also been used around the world.

Figure 2. Illustration of Passersby marveling at new gaslighting (The British Museum)

Most recent change in the technology of light source has been the introduction of LEDs, Light-emitting diodes. They have been developed since the 2000s into more and more reasonable alternative for most lighting sources. LEDs have become an extremely popular light source for street lighting due to the low energy consumption, long lifetime and good color rendering properties compared, for example, to the yellow light of sodium-vapor lights. The European Union launched an eco-directive in 2009, which aims to reduce energy use in all European cities (EU 2009). This directive banned the usage of mercury-vapor lights in European cities and pushed towards the use of energy efficient technologies, such as LED's. In addition to their eco-friendliness, they have an important feature of gradual dimming and brightening. Therefore they use less energy by dimming when there is less traffic and demand for lighting in the streets. Approximately 7 % of 86 000 outdoor lights in Helsinki are functioning with LED-technology currently, which is relatively little compared to cities like Milan, which has entirely switched to LED lighting (Milano 2014). However, due to the efficiency and stronger glare, the technology already has been criticized and claimed to be a reason to decreased quality of sleep of citizens, however the flaws are explained by unsuccessful lighting design (Moilanen, 2016).

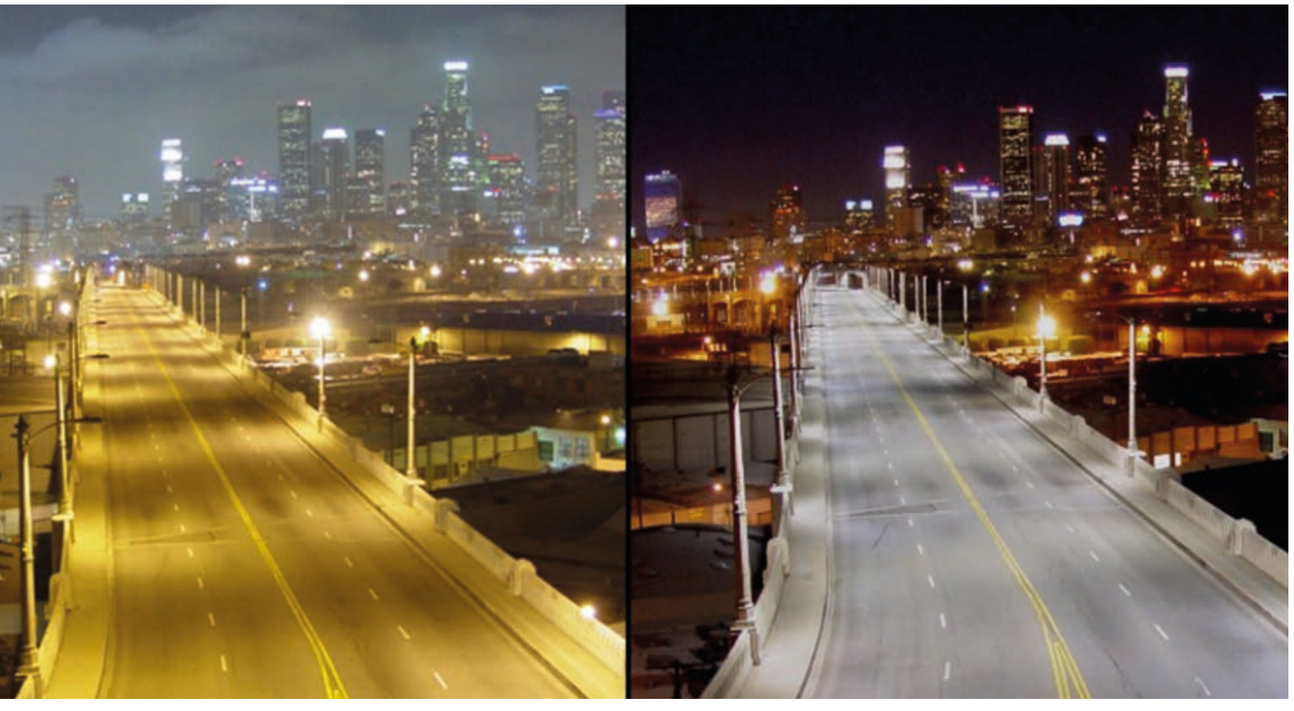


Figure 3. Comparison between light of sodium-vapor lights (left) and LED lights (right) (Los Angeles Bureau of Street Lighting)

2.2.CONCEPTS AND DEFINITIONS OF INTELLIGENT LIGHTING

Nowadays, cities are forced to cut down expenses due to the tight economic situations. For example, in Bangalore,India, the city turned off the street lights in order to save money but resulted in turning the city dark, desolate and dangerous place because of increased crimes and increasing accidents made possible by darkness (Kappan & Manjusainath, 2014). Many other cities have had to switch off the street lighting, for example the German village of Dörentrup where the lights used to be turned off from 11 p.m. to 6 a.m., leaving residents stumbling in the dark and an unsafe traffic situation. The residents came up with an idea of light on demand, which could be activated with a telephone call, and Dial4light project was born. Using the system is free of charge, and it is still cheaper for the village than running the streetlights through the night (Moore, 2009). The residents are satisfied with the solution although this would not probably work in the bigger cities. Light on demand is an excellent idea, however, the usage of it should be effortless for the citizens and lighter system for the cities.

Newest product development towards the light on demand has been the introduction of adaptive lighting, which is a lighting system where environmental and user-related data is used to control luminaires (Pihlajaniemi 2016, p.18). This consists of sensors that collect data about people and vehicles movements to change the amount of light to match the need. This system makes it possible to dim luminaries when there is no activity on the streets. The feeling of safety and support orientation are maintained by dimming the lights down to 30% of full brightness. Increasing the use of LED lights opens possibilities in dynamic lighting systems on a large scale. Adaptive lighting systems have been installed in many cities in Finland in walkways and motorways (Lumine, 2016).

The major need for the technology has been reducing electricity consumption. In 2005, lighting consumed 19 % of the worlds electricity, outdoor lighting amounting to about 8% of total lighting electricity consumption in the world (IEA 2006). Adaptive lighting has been proven to reduce between 20 and 40 percent compared to normal LED luminaire. Other potentials and benefits of adaptive lighting are the reductions of maintenance related costs and light pollution such as over-lighting, light trespass, and glare (Gibbons at al. 2014). Since the overall amount of lighting is reduced, problems caused by artificial lighting are reduced, like disruption of normal melatonin rhythms and ecological consequences (Navara & Nelson, 2007).

Studies on the use of adaptive technology for public lighting have been undertaken to examine the feeling of safety and how it could provide optimal light distribution for secure urban experiences (Haans & de Kort, 2012), while others have examined the subjective factors for the assessment of luminance distribution of adaptive lighting for pedestrians (Viliunas et al. 2014). Recent studies on the applications of adaptive lighting have shown that through such a technology, citizens could engage with public infrastructure and enjoy unconventional lighting in a public environment (Pihlajaniemi, 2016, p.148). There are concerns about the influence of

technology on traffic safety since information about the relation between usage of intelligent lighting and safety is not well studied (Bozorg Chenani et al. 2016), and in addition the increased amount of darkness concerns people, because darkness has implicitly acknowledged the possibility of danger or threat (Rauhala 2009, p.39).

Adaptive lighting technology has been tested around the world, as well as in Finland. In this thesis, I want to take a step further and study the possibilities of more intelligent systems. Intelligent lighting is a term that often refers to a part of the intelligent environment, such as an intelligent building. Another frequently used term in research contexts often denominated as smart lighting. Both of them are used to define automatic lighting systems optimizing resources. The term covers mostly systems where there is no human interaction. Interactive lighting is a concept in which users interact with the lighting. Sometimes it can be described as a subfield of adaptive lighting. Adaptive lighting can react to the user without their effort and also lighting can react to intentional user control using graphical user interface, a gesture or speech, etc. (Schmidt 2000).

The term intelligent lighting can also be understood as an umbrella term for all different kinds of dynamic, connected lighting and autonomous lighting. So far there is no existing example of an intelligent lighting system that would define the term perfectly; currently it stands for an idea of connected, interactive and autonomous lighting system. For clarity, I keep on referring to these technologies as “intelligent” in the same way as smartphones are called like that even though require human interaction to function to their full potential.

Figure 4 Adaptive street light system with a sensor by Lumine. (Lumine)

2.3.BENCHMARK

Some exceptional street light projects and products have been done in Finland and other countries. Most are solving the issue of safety, especially in a pedestrian crossing. Accident risk is up to two times higher during the night than during the day (Elvik et al., 2009) because of poor visibility. Especially in situations where different means of transportation need to interact, the accident risk and the gravity of it increases. The diagram below shows a connection between a number of accidents on pedestrian crossings and dark months (Tilastokeskus, 2016). As there is less natural light, more accidents occur. Artificial light of street lamps do not prevent all the accidents. Bad weather conditions, such as slippery roads due to ice can affect the results partially.

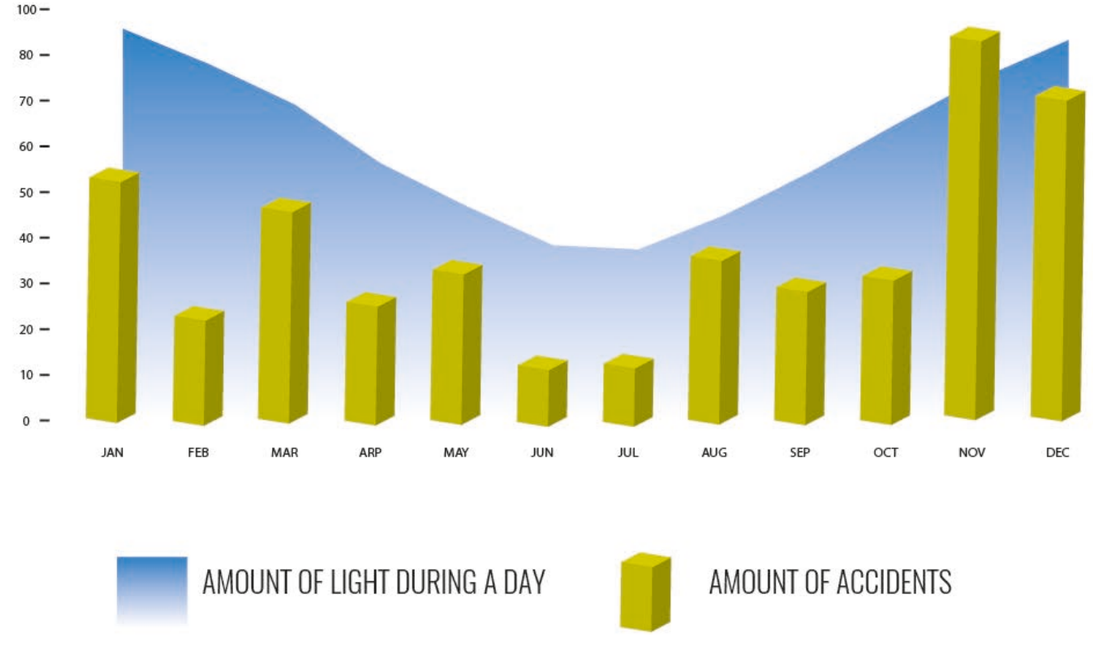


Figure 5 Statistics of accidents and daylight by Months

Heijmans BikeScout is a lighting system developed to solve the problem of insufficiency of artificial lighting in pedestrian crossings. It consists of the use of smart signals that warn drivers when cyclists are approaching a dangerous intersection. The system contains robust LEDs on a road surface that warn drivers from approaching cyclists which are detected with radar technology. The technology takes into account the speed of street users and provides signals in various configurations (Heijmans 2017).

Figure 6. Heijmans BikeScout system visualization (Heijmans)

There are also products in Finland such as Välkky a flashing light that activates when a pedestrian comes in its target area. The system is automatic and is mounted on an existing traffic sign pole. The device uses motion detection to sensor a pedestrian on a crossing and can transmit the sensor data to another device on the same pedestrian crossing using self-configuring radio network. The product is designed for northern conditions (Havainne 2017). There are some pedestrian crossings in Helsinki with this system and a study shows that there is some critique towards the effectiveness of the system. Alert lights of three different manufacturers were installed on the pedestrian crossings however results show that the cars do not stop for the flashing lights and according to the interviewed people said that the lights should start blinking earlier when approaching the crossings (YLE 2011). The technology itself does not solve the problem, and therefore the city environments, citizens and their needs need to be understood as a whole.

Some exceptional street light projects and products have been done in Finland and other countries. Most are solving the issue of safety, especially in a pedestrian crossing. Accident risk is up to two times higher during the night than during the day (Elvik et al., 2009) because of poor visibility. Especially in situations where different means of transportation need to interact,

Figure 7. Välkky in operation (Havainne)

the accident risk and the gravity of it increases. The diagram below shows a connection between a number of accidents on pedestrian crossings and dark months (Tilastokeskus, 2016). As there is less natural light, more accidents occur. Artificial light of street lamps do not prevent all the accidents. Bad weather conditions, such as slippery roads due to ice can affect the results partially.

Figure 8. C2 Smartwalk. Picture on shows the pedestrian crossing when there is no movement and on the right the system is activated (C2Smartlight)

3. TECHNOLOGIES OF THE FUTURE

In order to study intelligent lighting of the future, we must define how will the future streets be like. Intelligent will not be the only novel technology connected in a future city. Therefore, three technologies were chosen to be in studied alongside intelligent lighting. The technologies that were chosen from the desk research have a potential impact on the role of the future street lighting. The technologies are all feasible in practice although they are not yet broadly used. Many of these technologies have been lately discussed in public and they seem to be accepted by the users.

3.1. THE INTERNET OF THINGS

The Internet revolutionized the way to communicate and use information. Since the 21st century, people have become connected to the internet almost around the clock. We are now living the early phase of a new era known as IoT, which stands for the Internet of things. In 2008, for the first time in history, there were more devices connected to the internet than people. It is estimated that 50 billion devices are going to be connected to the internet and it is now a reality that even more is expected in the near future (Evans 2011).
As the name suggests, IoT refers to the connectivity to devices, instead of humans. The decreasing cost of wireless technologies and fast data transfer make it possible to imagine that in the near future devices are intelligently “talking” to each other’ to make our environments safer, easier live in and more efficient.
If street lights would be connected to the internet, their role within the infrastructure will be changed from a passive light source to a platform of information to the whole city.

3.2.SMART CITY

About half of the human population lives in cities, and the number is estimated to grow to 70 % by 2050. People need new kinds of resources which will need to grow linearly as the population develops. This prediction causes concerns in supplying resources and public services at the same rate. Transportation infrastructure will become burden environment and people if the same methodologies of today are followed.

Smart city is a vision of a city connected to IoT and other communication solutions that improve the quality of life for its citizens. Connectivity allows to reduce costs and increases the performance of urban services. Therefore, Smart City can meet the needs of overconsuming people by optimizing the resources efficiently and sustainably. New technologies have the potential to monitor and analyze processes and this way add value to the services that a city provides (Escolar et al., 2014). Important data, traffic count, pollution level, energy consumption and weather condition needs to be collected to ensure the development of the city. The production of sophisticated data analytics for understanding, monitoring, regulating and planning the city is a key issue underlying the idea of smart cities (McMillan et al., 2016). Continuous innovation is the essential idea of smart cities. Innovations require to have an insight of problems, which can only be found from the citizens themselves. The role of the inhabitants will evolve from the passive end user of technologies to co-designers of services and functions of the smart city. Intelligent environments are not used but lived in, and the experiences should be pleasing to all human actors who live, visit and act in the environment (Kaasinen et al., 2013).

Intelligent street Lighting can be envisioned to have a major role in infrastructure of smart cities as a platform for communication. Since street lights are placed in equal distance throughout the cities and have electricity all day, they have great potential network connectivity conditions. First, adaptive lighting saves energy and provides perfect illumination and safety. Secondly, it can be used to transfer data and also to communicate. Lighting could change to guide, inform or warn about anything that is happening on the streets. (SilverSpringNetwork 2015)

Figure 9. Sm!ght street light pole with charghing station (Sm!ght)

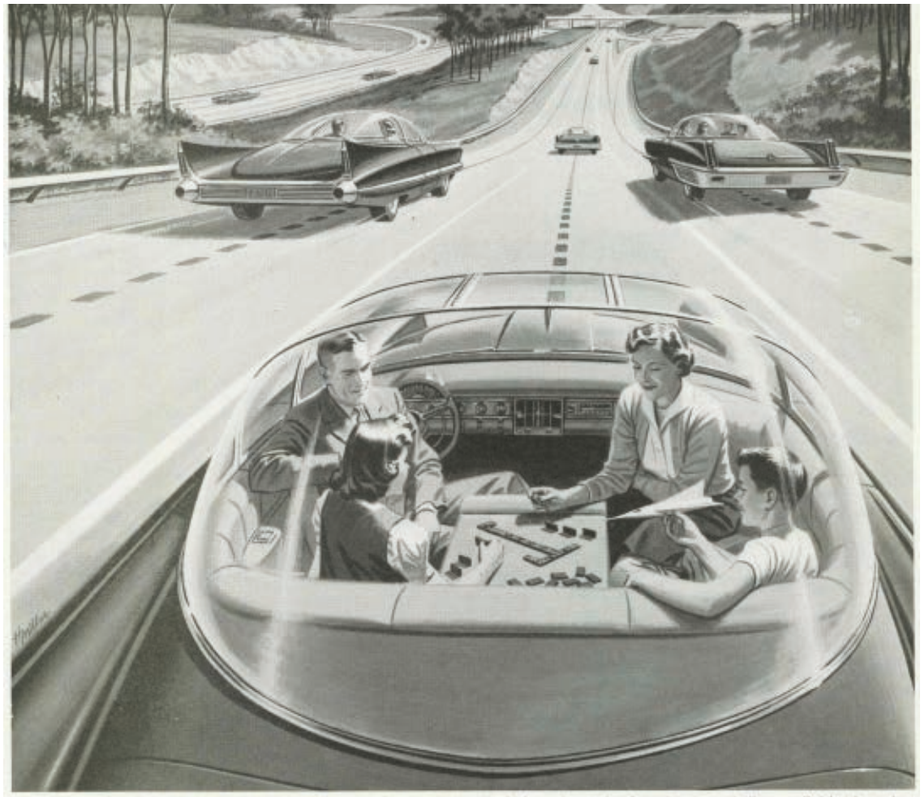
A German company, Sm!ght, has made a product of what intelligent street infrastructure could be, by providing street light poles with additional features. The poles have charging points for electric cars, Wi-Fi, SOS buttons and environmental sensors that can also sense pollution, noise, temperature, humidity and traffic congestion. All the data is virtually analyzed in real time. Multifunctional lighting poles also serve for other functions than illumination as well. This example shows how to move towards more active street light, evertheless it lacks the connectivity and the intelligence what is required for smart city infrastructure.

3.3.AUTONOMOUS CARS

In science fiction driverless cars have been imagined of ever since the 1930s. The first automated prototypes of automated driving were tested using magnets to track the road and radio control of speed and steering in the 1950s by GM and RCA (Weber, 2014). With more advanced and feasible technology this dream has become more realistic. Google has been developing an autonomous car since 2009 and since then many companies have been joining the development. For example, Uber and Volvo started testing autonomous logistics service in Pittsburg in the fall of 2016. Many companies, like Tesla and BMW, have launched vehicles with autopilot features even though law and technology still limit spreading of autonomous vehicles. An autonomous car is capable of sensing its environment and navigating without human input. Autonomous cars can detect surroundings using a variety of techniques such as radar, lidar, GPS, odometry, and computer vision. The advanced control systems interpret sensor data in order identify appropriate navigation paths, as well as obstacles and relevant signage. Potentially autonomous cars could reduce the number of accidents since the vehicles monitor their surroundings on much larger scale than a human driver can. Systems like Dedicated Short-Range Communication (ITS Standards Program, 2013) allow cars to drive continuously in the intersections by connecting with other vehicles. This could reduce traffic jams or even completely end them and, less energy is consumed when a vehicle is constantly moving rather than starting from 0 km/h.

The implementation of autonomous cars could change the role of street lighting. Since the autonomous vehicle itself does not require lighting to function, it raises a question whether the street lights should be on full brightness when there are only autonomous cars on the road. The street lights and autonomous cars could also be connected to share data to create safe information grid in a city.

Real-time connectivity of cars would allow traffic guidance and surveillance. This kind of infrastructure could be essential to make autonomous cars adopted, as there are a lot of people who do not welcome the new technology with open arms. It raises moral questions, such as what should the car do in a situation of evadable collision and who is in charge of driving. A tight network of Street lighting could provide secure, real-time communications. So far the laws does not allow autonomous cars in many countries, but in Finland, the law does not require the driver to be in the car while driving. For example, a project called Sohjoa was searching for interesting opportunities with automatically driving buses which tested publicly in Helsinki and Vantaa in summer 2016 in small scale (Sohjoa, 2016) which shows sociological interest towards the technology.



ELECTRICITY MAY BE THE DRIVER. One day your car may speed along an electric super-highway, its speed and steering automatically controlled by electronic devices embedded in the road. Travel will be more enjoyable. Highways will be made safe—by electricity! No traffic jams . . . no collisions . . . no driver fatigue.

Above: Figure 10. Sketch of autonomous cars from 1950's (The Everett Collection)

Below: Figure 11. Google autonomous car (digitaltrends)

3.4.LI-FI

The existing communication systems used today still cause concerns about the reliability and the speed of communications required for IoT and autonomous cars. The 5G connections, which stands for the fifth generation, are predicted to be used in the 2020s decade.
A new generation of communication can also mean that it does not use same technology as before. LI-FI is a high-speed and fully networked wireless communication technology similar to Wi-Fi that uses radio waves. Instead, Li-Fi uses visible light spectrum, which is ten thousand times larger than radio-waves. LED lights can produce this signal by flickering the light and sending a binary code faster than a human eye can detect. It provides local, secure connection between phones, computers, on any device that can detect and provide light. Because electromagnetic spectrum is around 10 000 times bigger than radio waves' spectrum, it enables for Li-Fi to be dramatically faster than Wi-Fi.

In private use, this means that fast and secure internet at home because the Li-Fi signal does not penetrate solid objects such as walls. Li-Fi can be dimmed to a level where human eye does not see the light, however data is still transferred. Li-Fi might be cheaper than another type of wireless communication technologies partially because it could reduce the need for costly mobile-phone radio masts, which also consume a lot of energy, mostly on cooling of the mast (Haas 2011) making Li-Fi technology an option for capacity and efficiency problems.
This technology has huge economic potential although it has not been implemented yet. In the streets, this could mean that existing infrastructure of street lights could be updated with Li-Fi technology and thus made into a communication grid. Since Li-Fi requires fewer components than Wi-Fi, this upgrade would be cheaper option.

Smart city's traffic would be guided, managed and gathered via Li-Fi street lights.
Li-Fi open possibilities also in direct and local the interaction between a person and the street lights. In other than car traffic situations, light could be communicated and controlled with an interface like a smartphone. The properties that are the accepted and desired level of control of public lighting provoke questions, that are discussed in this thesis later in chapter User research.

3.5.ENERGY STORAGES

In the future, people can become consumers and producers of energy at the same time. It can be produced by solar panels or by collecting energy from heating of a house. If the household electricity production becomes more popular, there will be more alternatives that are also affordable. Surplus energy can be sold back to grid. Producing and storing energy is beneficial to economy of an individual.

In a household and consumers can save a lot of money by being aware of electricity consumption. When the demand of electricity for is not big, it will be cheaper to use, and if houses still produce energy, it can be stored in household energy storages, which could be used later without buying or selling energy. When electric cars become more common they could function as energy storages in case they are not needed for transportation.
Measures to increase consumption of environmentally friendly and renewable energy are becoming more and more important for citizens and companies. Climate change, one of the biggest problem of humankind, has finally started to change people's attitude to eco-friendly products and consider them standards instead of alternatives, which can be seen in bigger markets. For example, Tesla announced its new mission, with renewable energy enterprise. The company produces now also energy storage products as creating solar roofs that are seamlessly integrated with battery storage (Ferris, 2016). People want more renewable solutions even if there is no direct benefit to the end user. The energy could also be shared to public usage, which enables more sustainable systems. However, it also creates questions about the boundaries of public and private electricity usage. Citizen motivation to share energy is also a question which still needs to be answered.

Figure 12. Tesla Power Wall 2 in a garage wall. The product has a capasity of 13,5 kWh (Tesla)

4.PRELIMINARY RESEARCH

With the technologies in mind introduced in the previous chapter I began to do design research about the intelligent lighting. In this chapter, I will describe in more detail the work done before the main user research and how it was conducted. After the desk research, it was important to a do more focused research locally. The research was focused on the capital area of Finland due to geographical reasons. Since the question was to study the relation between city and citizens in decision-making and development of street lights, it was essential to interview the professionals of the field and citizens. After the professional interviews, the first research with citizens were facilitated by prototyping an app mock-up and a survey, that evaluated the important technologies for different user groups.

4.1.PROFESSIONAL INTERVIEWS

Local information about street lighting is obtained most efficiently by organizing meetings with city planners. Experts of street lighting were interviewed in order to understand the local issues of street lighting in Finland. This was done to understand better decision-making processes of city administration' within the scope of public lighting. For design led inquiries, experts can a provide valuable perspective before starting to design for of a selected group of people (IDEO, 2015, p.43). For this purpose, I involved three experts on public lighting in the city administration of Helsinki and Vantaa to understand mindsets and attitudes of the decision-making for the city. Based on the desk research, twelve concept visualizations of citizen-centric services for public lighting were made and they were utilized as a central tool within interviews. The Construction Manager responsible for outdoor lighting in the city of Helsinki, Heads of Outdoor Lighting in the cities of Helsinki and Vantaa and a Designer of an architect group were interviewed.

The interviews began with questions about planning and decision-making for public lighting in cities. After this, based on the desk research, questions about the limited research on connected, intelligent lighting systems within large urban contexts and the challenges of conducting such studies were made. Questions about the city administration's approach to research on this topic were also made.

The interviews with the city officials were transcribed, coded and categorized. This data was gathered and further color coded onto post-it notes and converted into a full wall affinity diagram. Notes were attached to the wall and then clustered in groups by common sub-categories, which were later coded. The insights were then organized into main categories (Holtzblatt et al. 2005). The benefit of this technique is that it is fast to do and with the diagram, it is possible to see all the issues from different sources. Post-it notes were used to gain flexible alteration. After studying which were the major themes that emerged from the affinity mapping, I selected three most relevant categories which I will further present.

INITIAL CONCEPTS

In addition to the verbal interview, the city officials were also shown concept visualizations of lighting services and their possible functions as future urban infrastructure services, shown in following pages. The visualizations worked as mild provocations to the city officials let them express possible problems and further potential in the design concepts (Keinonen & Takala, 2010, p. 25). For this initial part of the study, I chose not to build and present physical prototypes to avoid paying attention to intended study factors. With concept visualizations, I could create a mutual foundation for understanding and explore alternative designs for the existing context (Bergström, Mazé, Redström, & Vallgårda, 2009).

The concepts were designed based on the desk research and initial understanding of possibilities of the possibilities of technologies. The feasibility of the concepts was intentionally speculative to generate different kind of dialogue than would happen in verbal interviews.

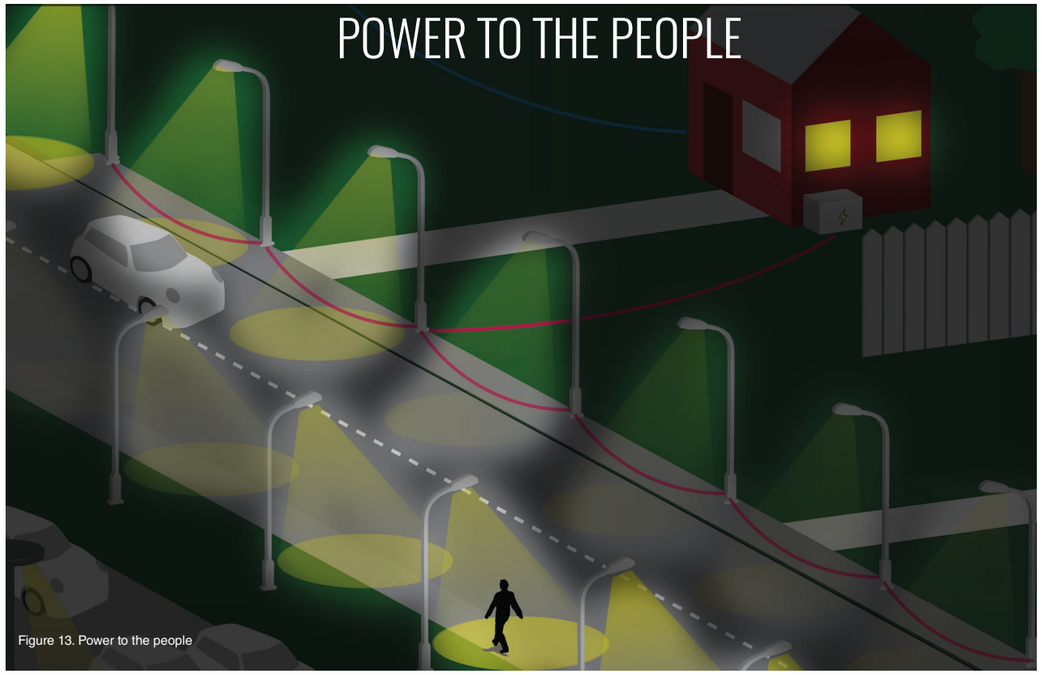


Figure 13. Power to the people

Houses are sharing the electricity with public street lighting. The house has a battery, that can be used to used to light the lamps when electicity is expensive. Citizens have better control of the light properties such as brightness and gain possible savings of electicity themselves.

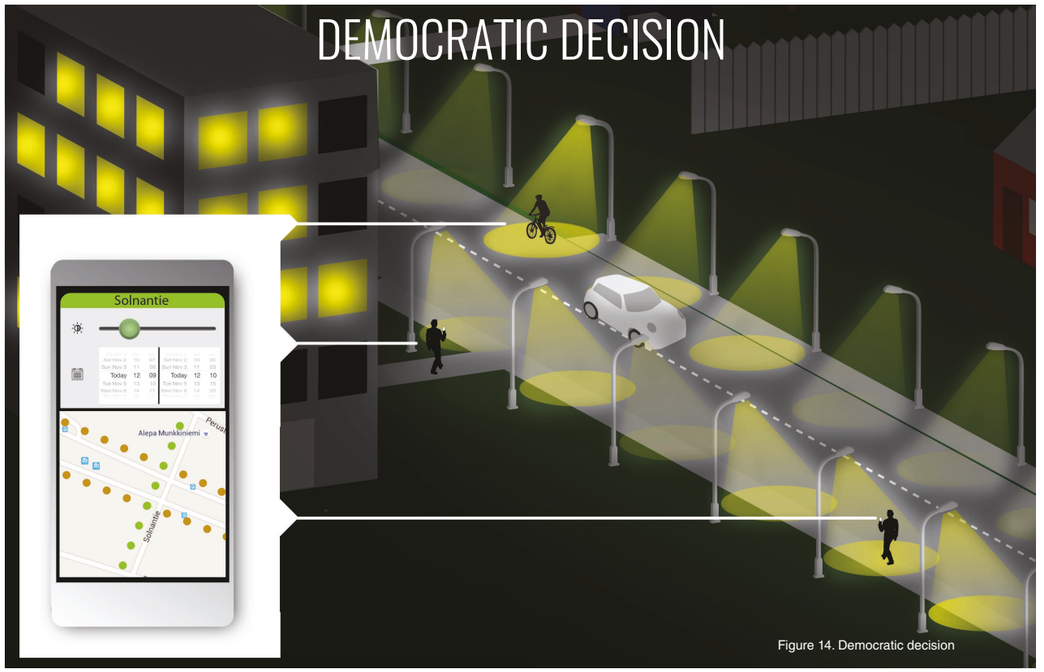


Figure 14. Democratic decision

People vote how they like their surroundings street lighting to be and the system starts to control the lights depending of peoples opinions. UI lets person to choose a street or path they are going to pass.

Figure 15. Light art concept

Light art following the surroundings of a pedestrian

Figure 16. Guidance

Guiding data projected in front of a pedestrian with helpful information

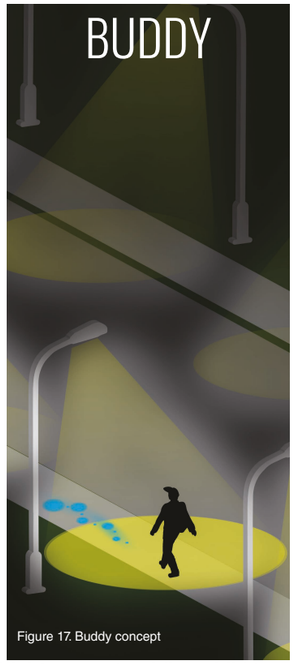


Figure 17. Buddy concept

Light mascot guiding child to destination to help with the fear of the dark

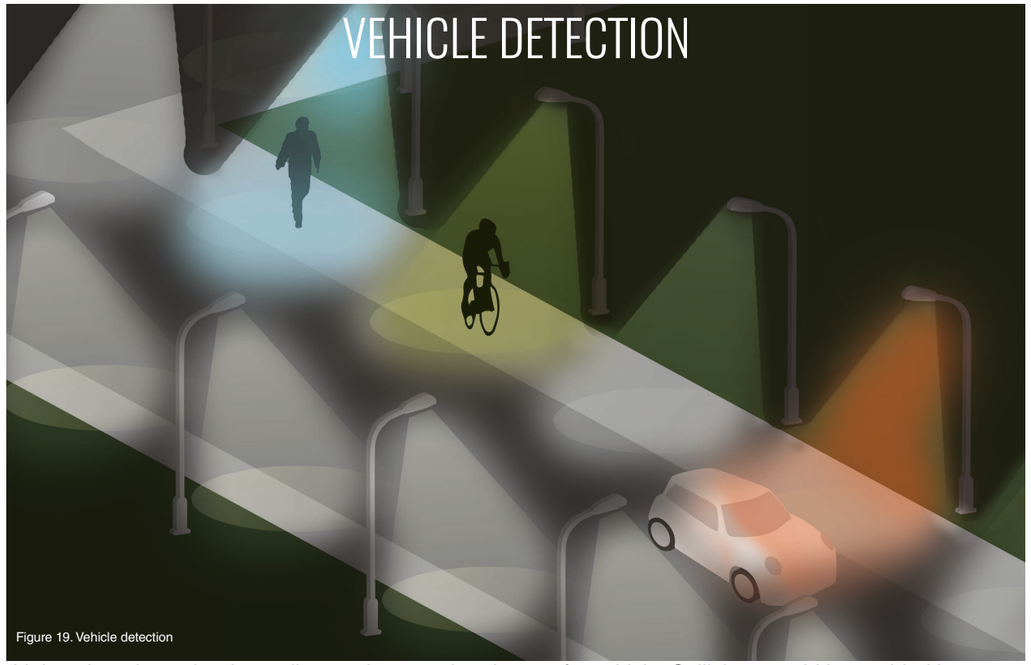


Figure 19. Vehicle detection

Lights changing color depending on the speed and type of a vehicle. Collisions could be avoided by seeing type of vehicle from a distance.

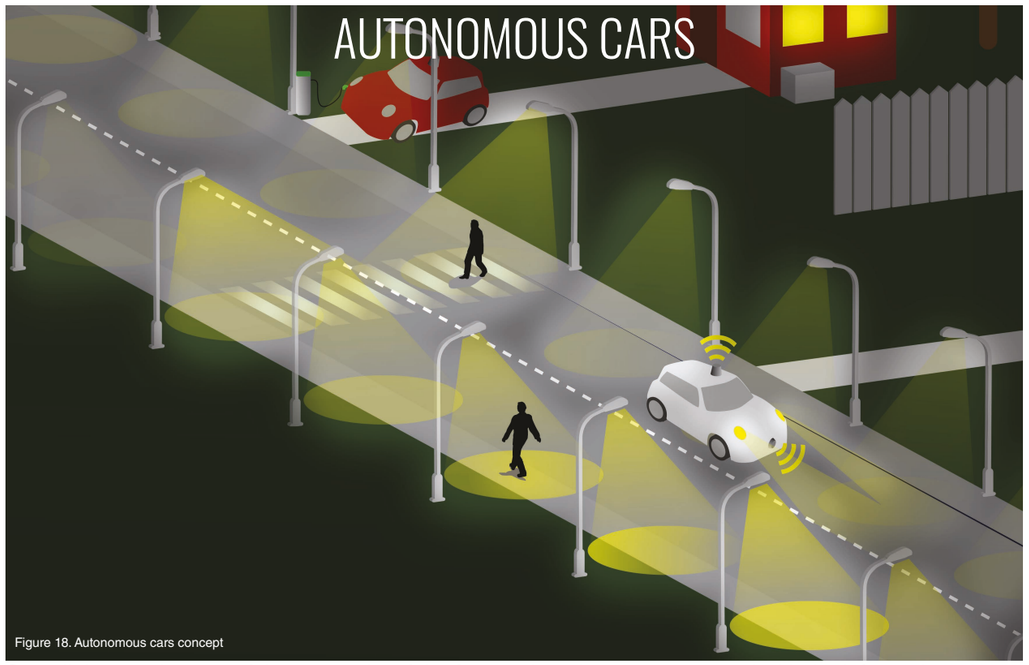


Figure 18. Autonomous cars concept

Streetlights can be part of the smart city of the future when they are connected with the information of autonomous cars. Streetlights could project pedestrian crossing where it is needed on demand. A passenger sends a singal to system and cars know to slow down when a passenger is crossing.

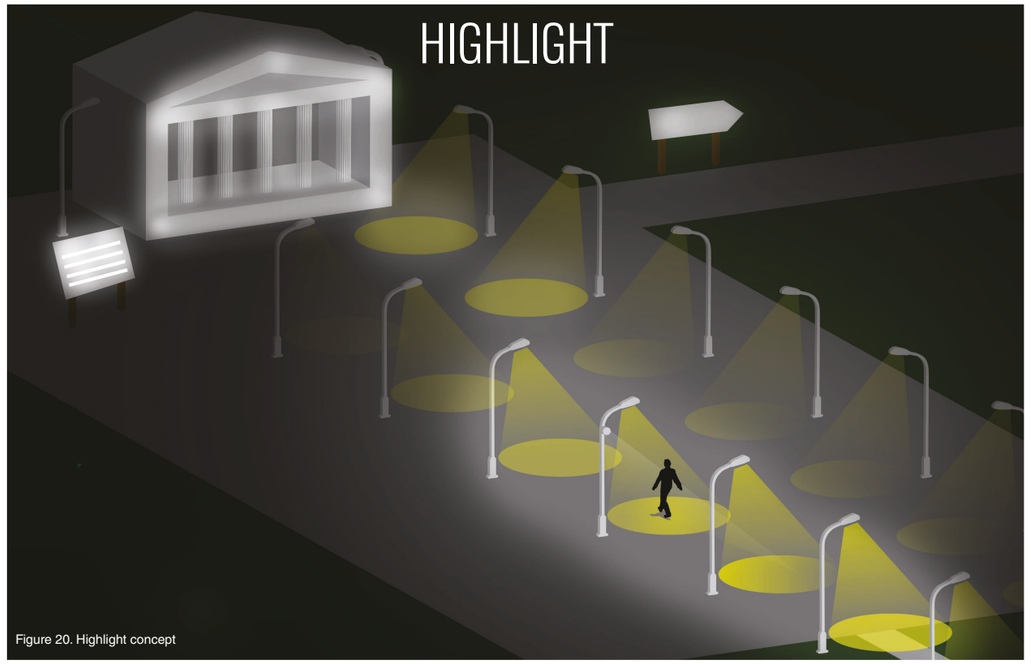


Figure 20. Highlight concept

Important elements of the surrounding , such as architecture, guidance and information, are highlighed when person is approaching. Sensors can tell the direction person is coming from. This concept works best during silent hours when people are not moving much in the city.

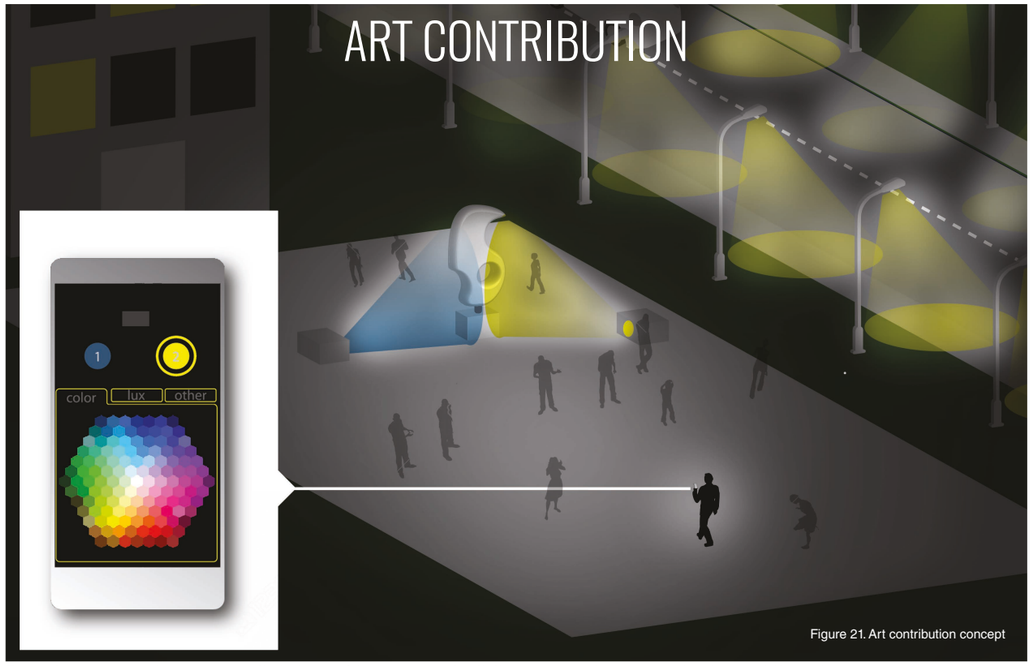


Figure 21. Art contribution concept

People get to take part on lighting of important buildings, art pieces and others. UI makes process easy and citizens get a feeling that they can take part on what their surrounding looks like and feel more connected to their own city.

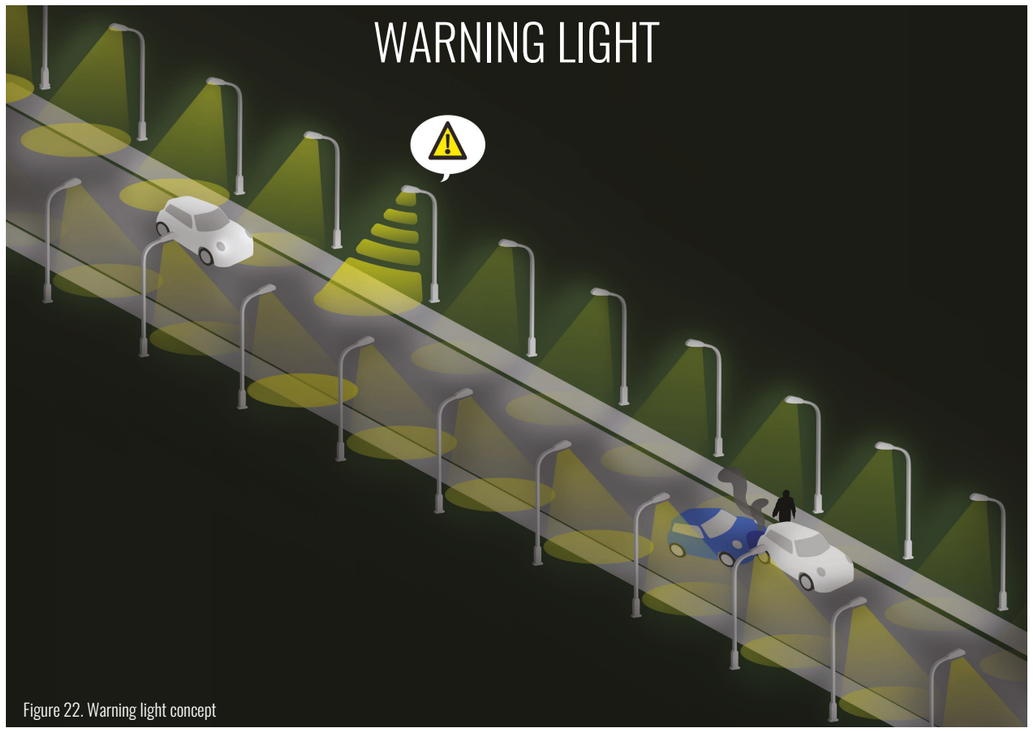


Figure 22. Warning light concept

Light is communicating by blinking in case of accident or other distrubance on traffic. Sensors can pick up unusual activity, such as blockage on the road and warn approaching car depending its speed.

Figure 23. Parking assistant concept

Light is guiding driver to free parking lot. Sensors track free spots and light them when a car is approaching from the entrance.

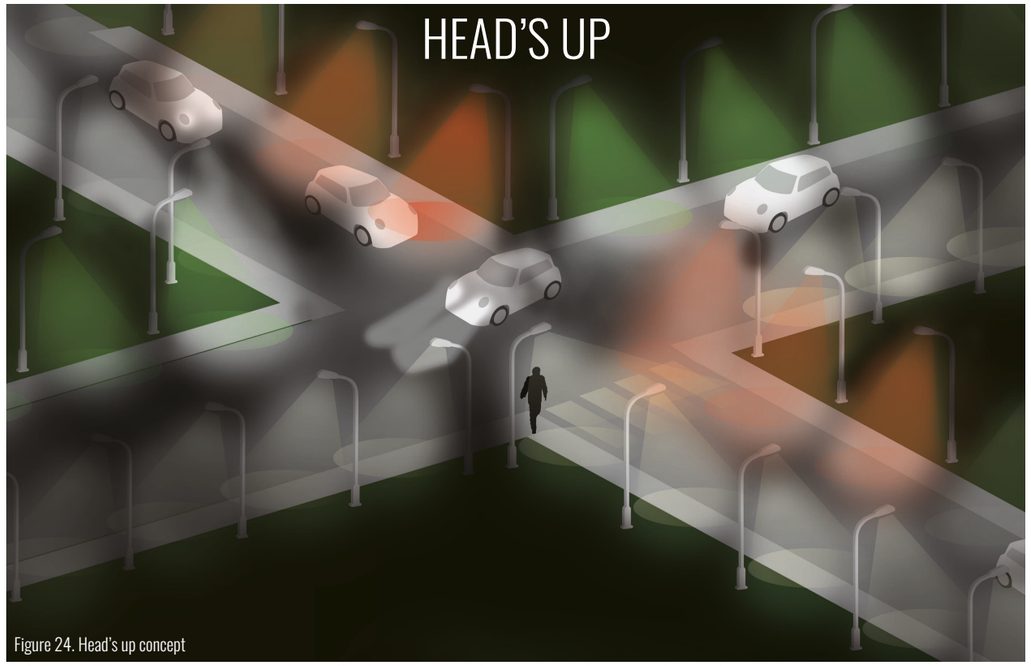


Figure 24. Head's up concept

RGBW LEDs are used to guide traffic by communicating to who should go forward and who should not pass. This solution could work as it's own or as an addition to traffic lights.

4.2.OVERVIEW OF THE INTERVIEWS

Information gained from the interviews gave a picture of the mindset and situation of two cities in Finland. The information was analyzed with affinity diagram and insights from different interviews were categorized in following topics.

FROM ECONOMICAL TO ECOLOGICAL: STANDARDS AND POLICY DRIVEN DECISIONS

The data from the interviews indicate that the city budgets, industry standards and policies have an impact on the planning and decisions of a large public infrastructure such as city lighting.
For instance current ecological policies influence the decisions. City administrations are also interested in energy efficiency and savings, therefore new future technologies such as adaptive lighting influence their decision-making. While rapidly evolving technologies with sensor technologies and digitalization of energy systems offer more choices for new service and business models for city infrastructure, finding and involving new and interested stakeholders into these processes are far from simple. The city administration interviews indicated that future technologies could generate savings, in maintenance, through energy efficiency and innovative services. One of the ideas was that street lights could provide platform 5G mobile connections, which would be paid by service providers, but so far the cooperation has been weak. Relevant and feasible service offerings that involve multiple stakeholders including everyday users of the infrastructure need to be implemented to lower the initial high costs.

SECURITY

Security is number one issue for the city when designing street lighting. Especially concerning traffic, the city planners had doubts and concerns towards adaptive lighting and shown concepts. Dimming is nowadays done astronomically, in other words, dimming is timed depending on the darkness in different times of the year. These settings are based on average usage of the streets; late in the evening on weekdays, there is less traffic on the streets and therefore less light. However, city officials were concerned about dimming the lights if there was no demand during normal a high usage time. Adaptive lighting would turn this situation around as the lights would not generally be dimmed but instead provide bright lighting in places where it is needed and highlight a pedestrian on a crossing with a contrast between bright and dimmed lights.
People do not notice general astronomic dimming, or at least do not react to it. To study new ways of using street lights citizens need to be pushed away from passive acceptance of how the street lighting is, to being an active part of decision making. Bureaucracy and laws are on the way of some innovations and testing at the moment. In the future, it might be easier for citizens to change their surrounding themselves if the city, which would benefit the companies and legislative side aswell. The municipalities do not have enough resources to evaluate all the street lighting and – this is where citizens could be used to gather, guide and transport information the streetlights.

LACK OF CITIZEN INVOLVEMENT

One of the major issues that was found out from the interviews was that user studies and research of different lighting technologies across different contexts were not widely done. The tests were done through questionnaires and surveys that evaluate and check already installed technologies. Choices of the administration are based on current standards and needs, thus engaging citizens further need not be useful. Two of the officials interviewed stated that they were not aware what people needed concerning future technologies. However, they also said that the lighting is for people, which is contradictory with the comment that city officials do not always know what people want from light in different situations. This shows how service design is not always seen valuable in some departments of city planning because some decision makers assume that they have the knowledge what citizens need from the lighting. Although user-centered approaches are an important part of urban design, which is for the present relatively little used. To achieve a more profound understanding of people responding to lighting, it is necessary to put people first, not technology (Boyce, 2014, p.214) and design can help out finding what people need. Especially with context of new technologies, designers are useful in lighten the user needs. Designers are experts in imagining things that do not yet exist and testing ideas and solutions without fine-tuned implications.

One of the problems with adaptive lighting was that expenses are cut in Finland, where electricity is cheap but sensors are expensive. It takes longer to adaptive systems to be paid back than it would, for example in the United States where the prices are different. Citizen participation could help to remove some responsibility from city officials to inhabitants.

CITIZENS AND CONTEXTS

The affinity mapping based on the interviews of the city officials helped in categorizing five different citizen user groups in different contexts of use. Firstly, this categorization was useful for finalizing the list of upcoming technologies and, secondly, then mapping their reflexive relation the various contexts of public outdoor lighting.

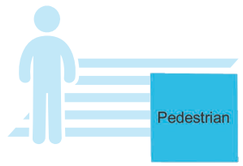
• Pedestrians, cyclists, drivers are all in traffic context, and they need to interact with each other in order to avoid accidents. Adaptive lighting is seen as a challenge especially in the crossroads and pedestrian crossings because different road users need to see each other in such areas.

•Dwellers living close to street lighting are influenced by it even though they are not using it. People complain about being irritated by street lighting, and therefore the changes in it that adaptive lighting would bring is seen as a problem

• Park goers require safety however energy is often wasted in such areas with little activity. Since the parks are isolated from the traffic, the city finds lighting controlling more useful there.

4.3.AFFINITY DIAGRAM OF INTERVIEW DATA

Pedestrians, cyclists, drivers are all in traffic context and they need to interact with each other to avoid accidents. Adaptive lighting is seen challenging especially in crossroads and pedestrian crossings because different road users need to see each other in those areas.



Lighting's focus is in safety

People do not cross just on the pedestrian crossing

autonomous cars – do pedestrian need to see them?

how do pedestrian benefit of autonomous cars?

Alerting car by blinking lights in pedestrian crossing does not work always

information about bad driving conditions

Light in parking areas repel thieves.

Adaptive lighting shouldn't be too flashy- shouldn't disturb

Does adaptive lighting make them more alert?

Path lit for ambulances

Parking lots are most annoying and dangerous places in the dark

bus drivers Drive a lot in same places

(Warning light) normal situations, like traffic jams, shouldn't be treated as a danger

Does adaptive lighting make them more alert?

Sensors to detect free electric car charging points

(Warning light) Warning blinking must work logically and correctly

Darker environment causes more accidents

warning signal would be a good thing when cars are part of the data grid

adaptive lighting in Kivistö is done for cyclists

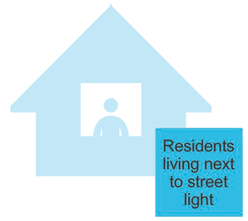
Bicycles are not going to be autonomous

As bicycles get more power, they become more dangerous

Tests of light brightening speeds and amounts for cyclists done in Helsinki

Light alarming about them could be good

Dwellers living close to street lighting are influenced by street lighting even though they are not intended to use it. Irritation of lighting from streets is being complained and lighting changes by adaptive lighting are seen as a problem.



Glare -> feedback -> dimming

Neighborhood could be given a code or an app to control the light

Using batteries have been thought of by energy companies

light colour causes complaints

"it's annoying to watch through a window how lights are dimming and brightening"

electric cars connected to a street lighting – benefits for both citizen and city

concerns that people who are inside and do not need the light anymore would turn it off

The light on the facades as well disturbs residents – cannot be solved by the city

how the controlling would be done?

different opinions between different users in the same spot

different prizes for battery usage than grid

EU regulations say that street lights should not shine to windows but it cannot be retrospective. new facades are not being lit.

Park goers require safety but often times energy is wasted in low utilized areas. Since they are isolated from the traffic, the city sees lighting controlling more welcome.

Parks are seen safer places to citizens to control light than on streets

Special alteration is possible with a code or an app

Lamp specific control is possible

-people could choose and effect in lighting

highlighting the environment in addition to path – to make it more enjoyable

New parks are done with sensors to brighten them

Sensors do not pay themselves back

light changing regarding schedules of dog walking and children play times

- OR this could be turned in "democratic decision

Light can be used as art in the parks

big potential for savings when there's nobody in the park

sport fields should not be lit in vain

playgrounds should be planned case specifically

light in the environment help orientation – if orientation is lost it is unpleasant

create a theme for different places with lighting

Light on benches for reading etc. on demand

4.4.PROTOTYPING APP MOCK-UP

From affinity diagrams of interviews, it was possible to narrow down topics to study and start doing research with users. Citizens needed to be involved in process in order to go deeper with the issues that evoked from interviews. The aim was to do research with user-centered design approach.

The first attempt to do user research was done with use of an app mock-up, with the insights gained from interviews. With the app, the user could control the street lights with Li-Fi and there would also be a motivating reward system of energy production. The app was designed to study the needs of citizens by provoking their thoughts and asking them to generate ideas around the suggested features. The ideas of features were generated from the expert interviews and desk research. The app allowed the user to change brightness and color of the light in a park. The reward system collected points, which user could receive by installing a sensor in their own window. This sensor would be used to dim and brighten the lights of adaptive light pole in a stable condition of households. Points could have been received also by registering an energy generator or energy storage. Additional points could have been collected by reporting condition on the road, error on the lamp or by making light related suggestion.
The app gave a possibility to plan and comment lighting plans with 360-degree videos, which could be looked at the app. This feature was there to help citizens to be part of the decision-making process by making the visualizations and plans to be more realistic and experienced in illustrative form. The citizens

By constructing a mock-up and testing it fast, it was evident that the features in the app mock-up were too suggestive and it did not give space for citizens to ideate features of lighting.
Also, there was no proof that the issues in the app were the ones that citizens face or even are interested in future infrastructure. I decided to take a step back and be more collaborative in involving the citizens. This conclusion was clear to me only once I had made the mockup. Making is a great way to think, and it helps to bring focus into designs and this kind "fast failing" is welcome in human-centered design (IDEO, 2015). It is better to make mistakes at the beginning of the process and learn from then than to do them at the end of the process or discover that ready design does not meet the needs of users.
As mentioned before in chapter 1.2., citizens need to be involved more in the development. User imagination and value proposition needed to be studied more before this phase. A better understanding of what are the needs and desired technologies, was needed from the chosen user groups. Therefore, a technology user matrix was done, which is described in the next chapter.

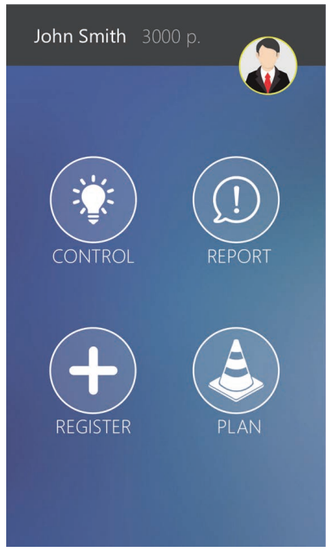
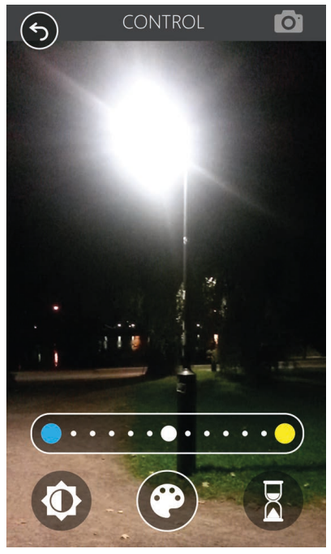
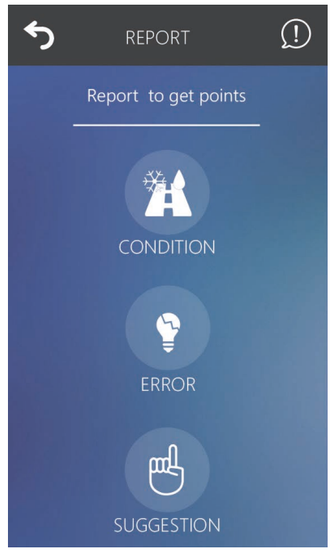
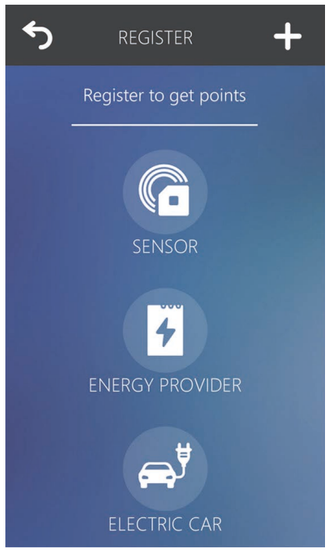


Figure 25. App mock-up screens
Above: Home screen
Middle row, from left to right: Controlling a street light, reporing, registering
Below row, from left to right: connecting a energy provider, connecting a sensor, connecting a electric car







4.5.TECHNOLOGY USER MATRIX

A quick survey was facilitated to determine relevant technologies and for different contexts of use. The survey consisted of twenty randomly chosen people in Aalto University and from circle of acquaintances in Helsinki area. Since the survey took longer than 5 minutes to answer, most participants were from circle of acquaintances. Participants evaluated the possible functions of smart lighting in situations from the perspectives of the five user groups. The interviews were to find out in which contexts, in citizens' opinion, intelligent street lighting could have a major impact on future cities. Another aim of the interviews was to generate ideas about what the technology could do in those contexts.

By adding three different technologies of the future, smart lighting could be envisioned from different aspects without limiting the imagination and ideation of users. Users were asked to evaluate the possible functions of smart lighting in situations where autonomous cars, Li-Fi, and household energy storages would be used. These three situations were evaluated from the perspectives of five user groups. Statements were in form "If there were **[autonomous cars]** in traffic in the future, smart street lighting could have an effect on **[pedestrians].**" where "autonomous cars" represent a technology and "pedestrian" represents a user group.
In the evaluations of the statements, a Likert scale was used, because it provides a range of responses to a given statement (Cohen, Manion, & Morrison, 2013). The statement was asked to be evaluated on the scale from one to five, number one representing "I do not agree" and number five presenting "I agree." Users were asked to validate their answers with open answers to present ideas or thoughts by using open answers. Interviews were to enlighten the background for the validation since in human-centered design it is all about listening to the users in their words (IDEO, 2015 p.39).

Figure 26. Technology User Matrix results

The results were analyzed by comparing which claims were the most supported. The results (Fig. 3) showing attitudes of people towards the relevance of upcoming technologies onto public lighting is presented above in the Technology User Matrix. As figure shows, the participants answered that there were implications for drivers, cyclists and pedestrians and their experience in street lights in case there were autonomous cars on the roads. The Matrix also indicates that the experience of pedestrians and park goers could be influenced if street lights were streaming information through Li-Fi technology. It also shows energy storage through domestic batteries that could play a role to residents if it interacted with neighborhood lighting. With this, the research proceeded into the inquiry of these hypothetical contexts of future technologies for the context of public lighting through three design based procedures. The subsequent sub-sections of the thesis will concisely discuss the three design procedures undertaken with a mixed set of participants.

From the technology user matrix, the most important result was the voting of the user group and technology combinations which helped to plan and focus on user research. Most important user groups to autonomous cars were pedestrians, cyclist, and human drivers. Li-Fi was most relevant for dwellers and parkgoers and energy storage dwellers was most relevant.

IDEAS GENERATED FROM TECHNOLOGY USER MATRIX

Overall, intelligent lighting was seen as a possibility to decrease accidents and collisions in cities. Especially when connected to Li-Fi, Autonomous cars' activities could be communicated by lighting. Streetlights could warn other traffic about danger and avoidable collisions at street corners. With this kind of connectivity, it would be possible to have adaptive bicycle lanes, which would be lit by color coded light in different parts of the streets depending on the number of cars in traffic.
Li-Fi was found valuable in applications of traffic and for activities of park goer. Cyclists context divided opinions because the cyclist is not actively using a smartphone while driving. However, Li-Fi connections with a phone could open possibilities. Dwellers were seen to benefit only from Li-Fi with an internet connection of light and possibility to control the lights in front of the house. Although, respondents often understood the responsibility of controlling the lighting of traffic from home.
In a park, there are two kinds of needs for Li-fi light: Safety and amusement. While parks are made for citizen's pleasure, it can also bring feelings of unsafety because of less light and obstacles like bushes. Security was considered an issue mostly among young adult women.

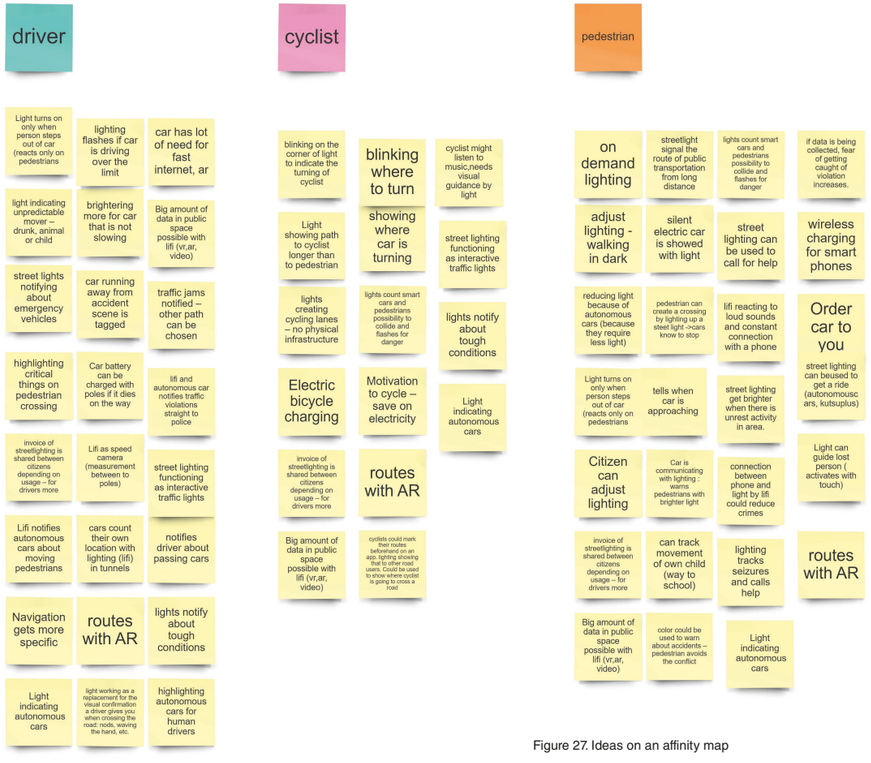


Figure 27. Ideas on an affinity map

Creating more security with the connectivity of Li-Fi could make people feel more secure when moving alone in dark parks. Amusement was suggested because of the high amount of wireless data provided by Li-Fi. Light games and atmospheric lighting were suggested to add value to parks in the dark. Functionalities like sports tracking and real-time utilization rates could provide functional services with lighting.
Energy production was found most useful to dwellers since it can be easily done in a house or apartment. Stored energy would be used to benefit individuals and also for communities like lighting up a greenhouse owned by the neighborhood or building. The whole system of energy paid by taxes was challenged with a thought of payment system depending on the usage of street lighting, which would mean higher prices for the car drivers since they travel longer distances. Cars could be part of production because of the increasing number of electric cars. The benefits of controlling the lights gained from stored energy would preferably be done in parks, where the energy is used for entertainment and leisure.

To summarize, the issues that were risen from professional interviews were filtered into technology user matrix which was used to evaluate the importance of the technologies to different user groups. Most relevant user-technology combinations were chosen to be studied in further in more intense user research. The chosen groups of use were park goer, dwellers and drivers, pedestrians, cyclists, which were merged category of traffic. The ideas aroused in technology user matrix were used to ideate the design research sessions.

Figure 28. Ideas on an affinity map

5.USER RESEARCH

This chapter explains the main user research done in the thesis. The preliminary research helped to focus on the main user research into most relevant topics. All the three methods, workshop, app mock-up and scenario building sessions, were used to gain information about users' needs and ideas of intelligent street lighting. The aim of the research was to get ideas of chosen contexts of use of streetlights and deepen the understanding of the citizen's needs and relation to street lights. Also, research was done to see if the methods helped people think about their surrounding infrastructure differently and if they felt that they could be part of decision-making. The participants who were chosen to take part were chosen without restrictions, because all citizens of city were seen potential to generate ideas and provide important insights of street lighting.

Three different design sessions were held with different technologies and contexts. The objective was to study three different technologies, Li-Fi, autonomous cars and energy storages with relevant contexts of use. Other technologies were involved in a secondary role in some sessions (fig #). Three methods were chosen to activate people to image future street lights to generate optimal data. Another objective was to demonstrate different ways to get user data. First, all three procedures are explained and afterwards analysis of the data gathered is presented.

	Autonomous cars	Li-Fi	Energy storages
Traffic (drivers, pedestrians, cyclists)	Workshop	Workshop (secondary)	Scenario(secondary)
Park goers		App mockup	Scenario(secondary)
Dwellers			Scenario (Primary)

5.1.SITUATING A LIGHTING APP WITHIN A PARK

The aim of this design procedures was to explore people's experience public lighting in a park environment. The prior desk research (Pihlajaniemi, 2016) had directed the themes of safety, amusement, and community for this context and I had those themes as a starting point for this procedure. A mock-up of a mobile phone application was prototyped for simulating a user-controlled interactive park lighting service that address the above themes. The simulation was done through mobile screen transitions to trigger an imagination for the functionality of the lights. The application simulation as a design inquiry referred to Situated and Participative Enactment of Scenario (SPES method) as a tool for envisioning ideas about services in their natural setting, where an idea can be proposed by the user or the designer (Jacucci, Kuutti, & Ranta, 2000) within a use of context. This procedure was carried out in a park with nine voluntary participants in park in Helsinki, who were chosen randomly to gain as various participants as possibly. The testing was quite low threshold for participants and that is why it was natural to ask park goers to try the app mock-up.

The control of smart lighting in public spaces and possibilities through the Li-Fi technology were first introduced to the participants. Then they were taken under a light pole in the park and given a mobile phone with the mock-up application. Having been explained the navigation and features of the app the participants were asked to imagine how the lighting around them could change when using the app and which additional functionality could be useful for them. The app provisioned ideas but functionalities were intentionally left open to encourage people to propose and develop new functions and reflect on their proposals on site at the park. The conversations were audio recorded and documented through photos. The data consisting of the conversations and proposals made by the nine participants were analyzed for this procedure.

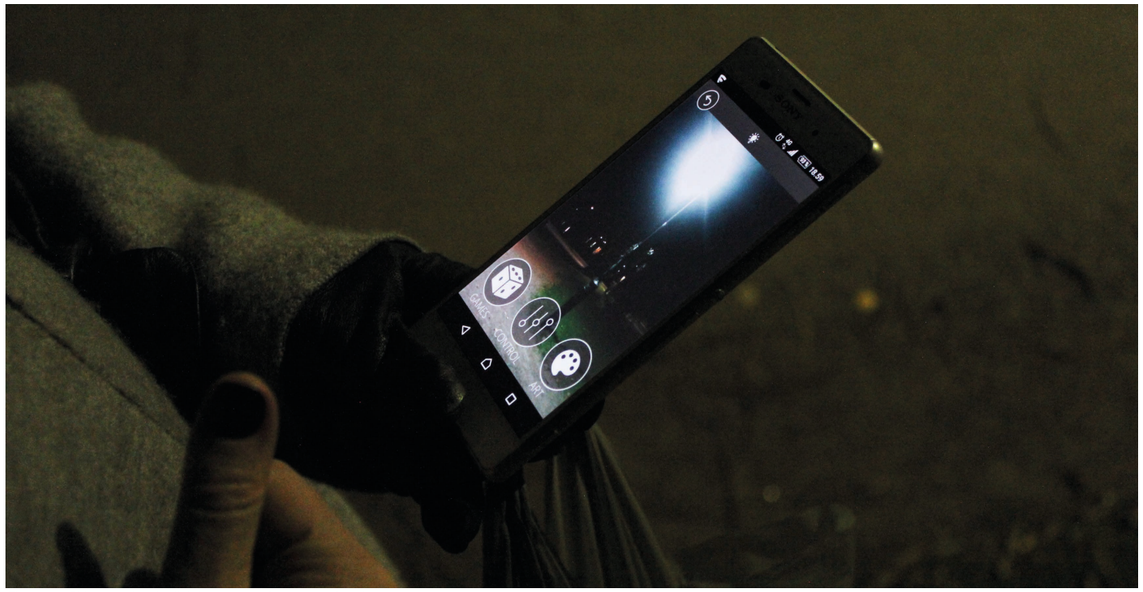


Figure 29. Citizen testing the lighting app mockups control settings

App operated to stage and simulate a dialog and ideation within citizens' everyday lives. Sessions were held in a public park after during dark hours of a day. Test persons were asked to try the app to envision ideas for services and ideate functions as the issues arise. The app proposed a basis of ideas but the functionalities were intentionally left open to encourage people to propose and develop ideas. Some features in the app were left intentionally open to gather more broadly ideas, thoughts and concerns from citizens. In the beginning, people explained the idea of smart lighting and the possibility of controlling lights in the park using Li-Fi, which was also briefly explained. People were encouraged to think that anything would be technically possible in the future.

In the beginning, some features caused a concern of conflict of interests. Although, as people were ideating they tended to get excited and did not talk about the problems anymore. This was one of the reasons why user-centered design helps ideas to become a reality because people are more open towards their ideas and are ready to push them forward.

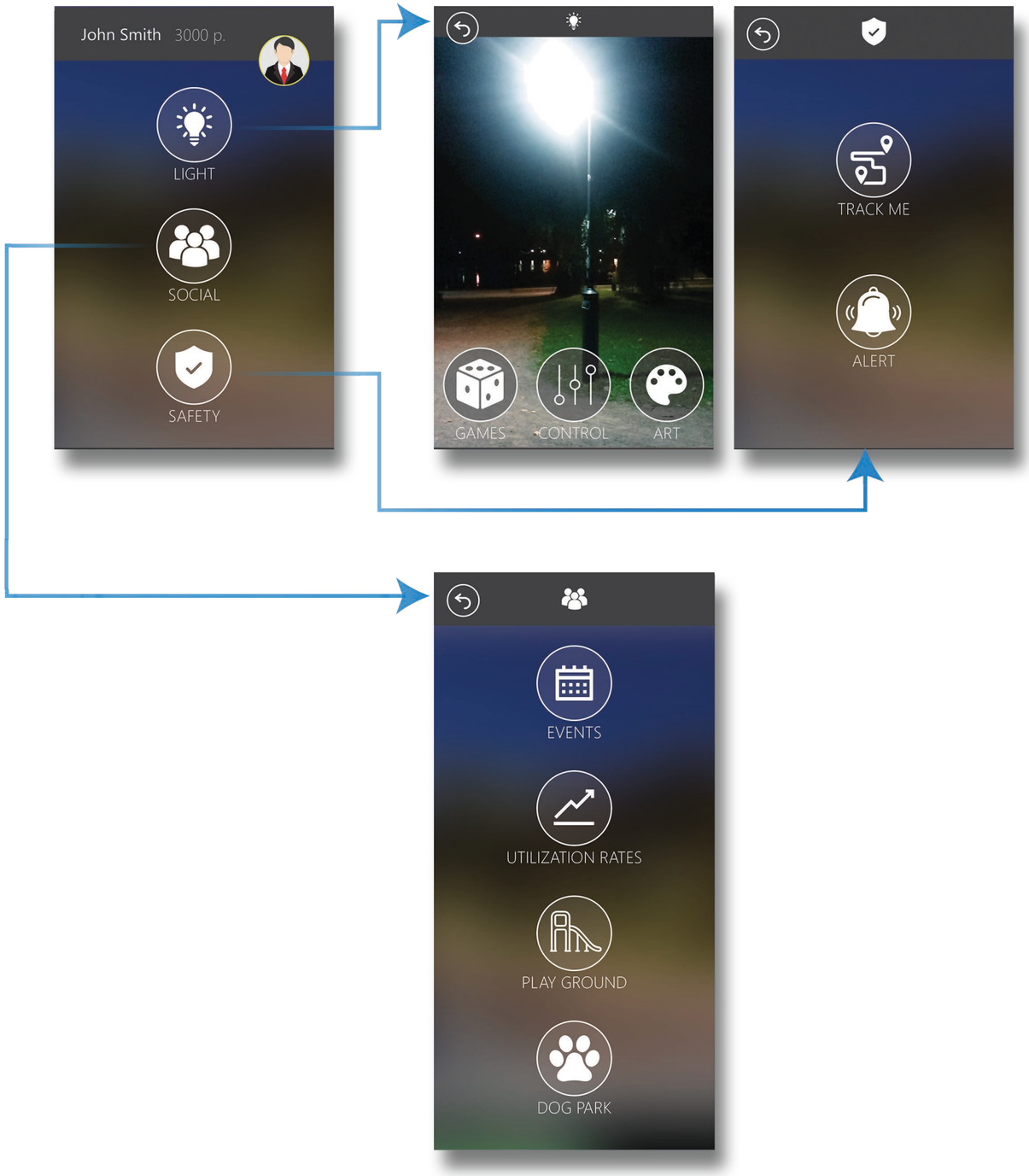
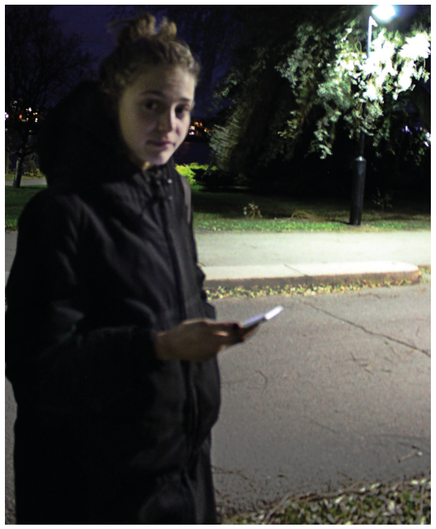


Figure 30. App mock-up screens. The main screen has three main categories: Light, social and Safety. Under them, there were some features with suggested in detail and some indefinitely. Some people generated more ideas with open features, and some liked to comment more on the suggested ideas.

Being in the situation where lighting control would happen in real life helped people to ideate own features into the app and explain them. For example, an older lady wished that a piece of art that she knew that was in the park could be better lit up. When she was trying to point at it, she could not find it in the darkness. A moment later, she noticed that it was right next to her. The security feature did not generate as many solutions towards the reduction of crimes as I expected. The suggestions often concerned helping in an emergency situation and people who are lost in a park. Especially people with memory problems could benefit from guiding lights in a park. Nobody wanted to be tracked although they could use tracking for own children or elderly who need help. The results of testing were versatile, and the meanings behind the functions were quite different from the ones that I had expected while designing the app. People are very different with their needs, problems and wishes. Therefore, one individual cannot predict them all alone, even in general context like street lighting. Once again, user research showed its value in the development of services.

Figure 31. Citizens trying the app mock-up

Figure 32. Citizens trying the app mock-up



I'm retired, I move outside during day time more and stay indoors when it is dark. if lighting would work better, I would feel safer then maybe I would move more during dark.

I'm most involved with street lights in playgrounds with a four-year-old, there firstly I hope that there would be some sort of lighting but then it would be quite fun if you could set a game with them. in November it would get the kids out better. Then it could be a nice addition because that sitting in a sandbox is not fun anymore

We have sometimes arranged a picnic in a darkling summer night and brought there some candles but it could be fun if you could get atmospheric light in the evening. Winter nights like this it could bring quite a lot more if you could order or turn on lighting.

5.2.ENERGY PRODUCING SCENARIO

The second design procedure was about the residential dweller's context. The focus of the inquiry was on two aspects. First what citizens thought about sharing and selling their energy for their neighborhood street lighting, and secondly how they perceive the benefits because of selling or sharing their energy to the city infrastructure.

This procedure was based on a design workshop format but incorporated the tool of scenario completion with visual prompts (IDEO, 2015, p.109). A total of ten people participated in this procedure, from circle of acquaintances and voluntaries from Aalto University Design Factory. The scenarios were made with co-creation sessions using sketching techniques and visual prompts. First, people were introduced with an idea of producing energy in households through a distributed solar system and battery storage in their homes. Then they were told about the possibility that a part of the energy could be shared to the public grid and to lighten their immediate neighborhood. Next, a set of visual prompts were presented as a day in the life of a person living in a suburb with adaptive smart streetlights. Then the participants were asked to imagine what this smart street lighting could do in particular situations that they choose. The sessions were carried out by placing visual prompts on the table alongside empty sheets of paper and people were asked to write of draw what their neighborhood street light could do if the energy storage of their home contributed to the lighting of their street.

In the second part of the procedure, people were asked to look at another scenario. There the usage of street light of each user would be tracked, and they would be charged by the city for that instead of paying taxes. The idea was to provoke people to rethink about their behavior and values. This raised discussion on public and private energy production and usage and citizens' privacy. It also opened new discussions of control and demand of energy sharing. The provocative scenario was always asked after the first scenario building to make people validate the ideas they generated, since the attitude changes if one needs to pay extra on additional feature. These conversations were recorded, and the papers with writings and drawings were documented for further analysis.

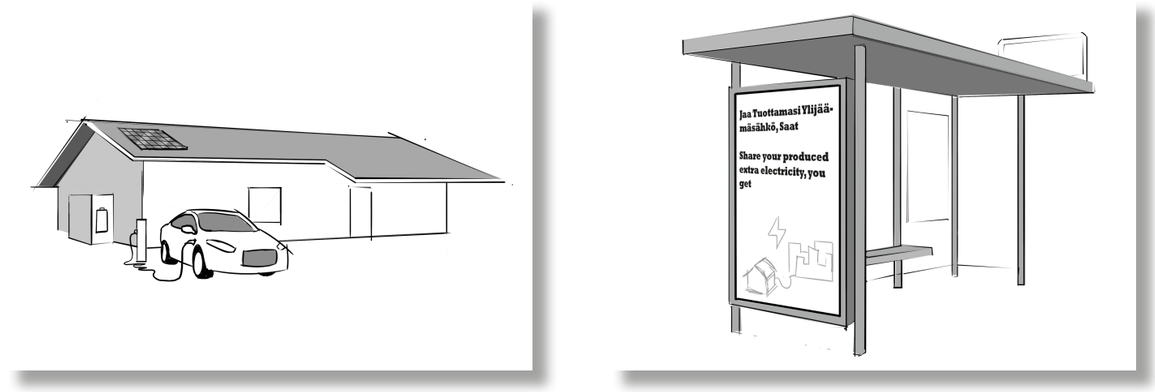


Figure 33. Visual prompts. left: House with energy sources and storages. Right: Advertisement to share energy

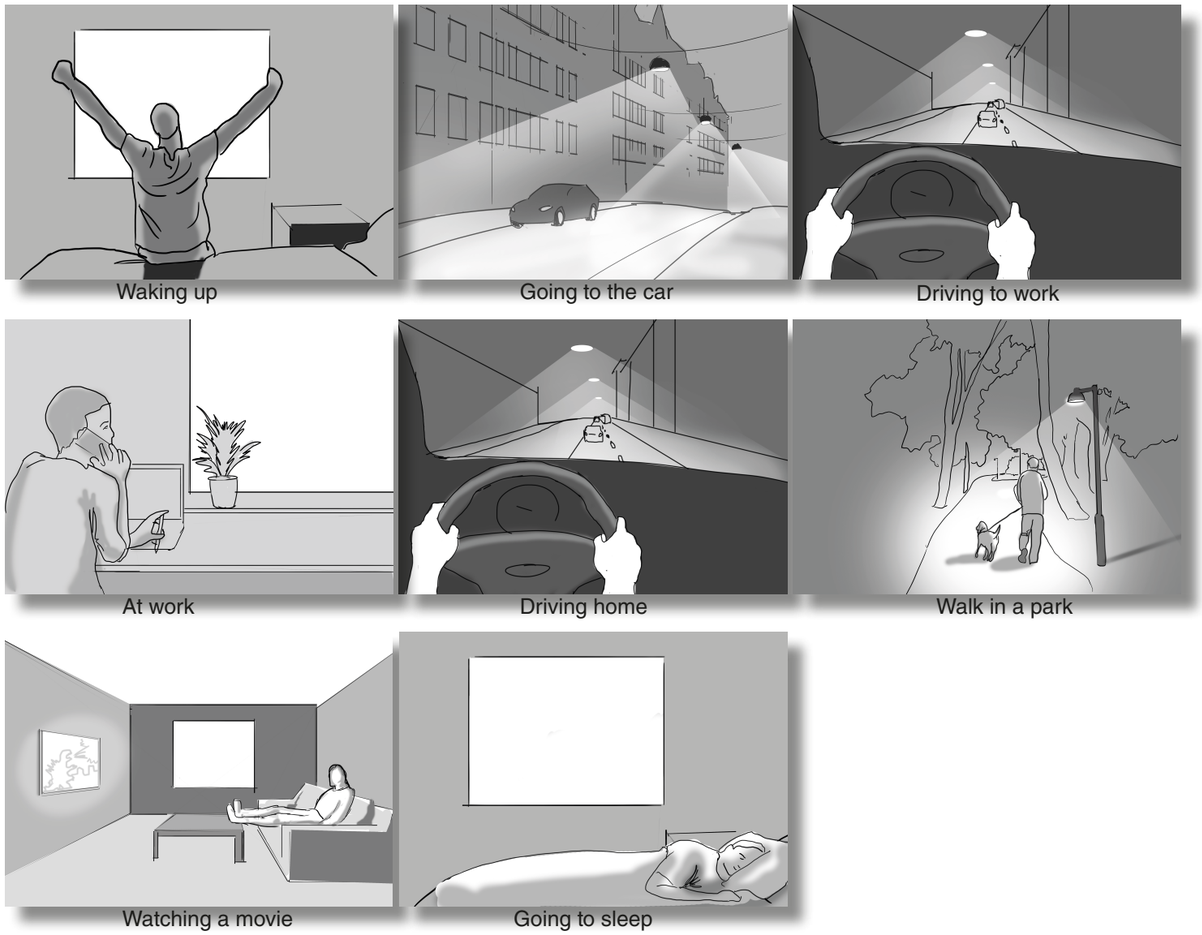


Figure 34. Visual prompts of the scenario

The focus on these sessions was in the role of the street lighting when a person is inside. Other situations were shown to see if the test persons generated more ideas and if the situations made more sense for people. The hypothesis was that people might find it too unconventional that people inside a building could control lights outside. The results of the sessions showed that there were lot of ideas of how the light could meet the needs of the dwellers. However, there was also an understanding of the responsibility of dweller. Some suggestions on how the light could be controlled so that it would not annoy or compromise the safety of the street user were made. Some situations in the scenario did not result in that relevant ideas, for example at work-situation did not generate several ideas, partially because people often work during day time and they need to focus on work. Other ideas than intelligent street lighting were also taken into account. Traffic situation generated ideas about car sharing and autonomous cars even though they were not introduced or mentioned in the procedure.

Next page: Figure 35. Citizens taking part in scenario building sessions

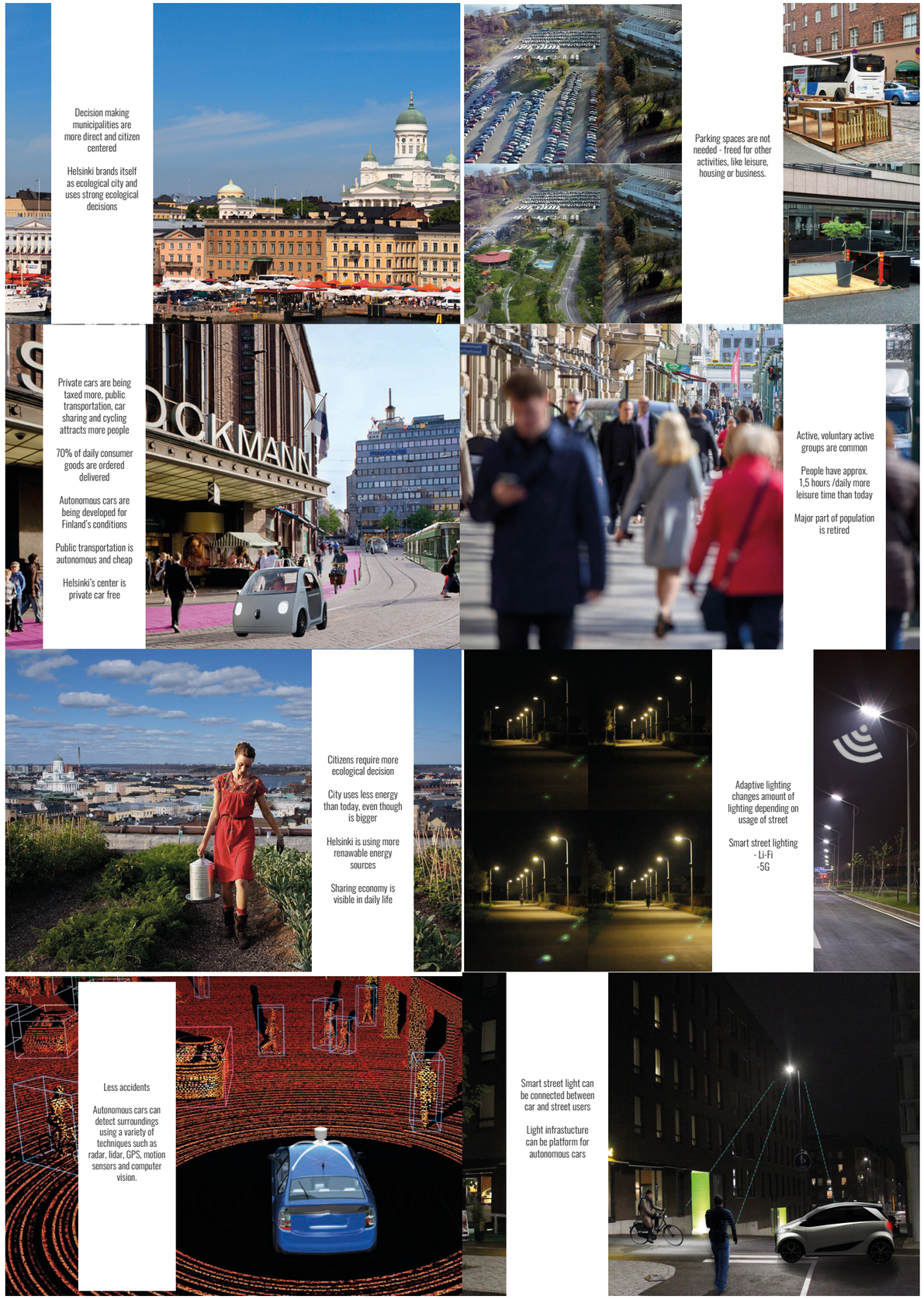
5.3.IDEATING WORKSHOP FOR FUTURE AVENUES

This procedure addressing the first three categories of user, driver, cyclists, and pedestrian contexts was in the format of a design workshop. The aim was to discuss with citizens the future of public lighting in the age of autonomous cars and connected traffic. If the traffic is revolutionized, then the role of lighting could also be changed. Around 30 people were invited directly, which some of them were city officials, some university students and some from circle of acquaintances. Six participants agreed to participate in the workshop. They were divided into groups of two for cyclists, pedestrians, and drivers. The setup was provisioned with pens, papers, and post-it notes. The question that guided the session was that if the nature of traffic were to change in the future then how could we approach the role of the lighting of the roads? The workshop was a verbal and visual brainstorming session within a selected group (IDEO, 2015, p. 94).

The session began with a vision document presentation of Future Helsinki in the year 2030. This vision, based on the PESTE analysis tool, comprised political, economic, social, technological and ecological issues (Johnson & Scholes 2001) concerning Future Helsinki. Participants were divided into groups, cyclists, pedestrians and drivers. Then a task to fill in sentences was given to the teams.

[An app / A product / a service] that... uses smart street lighting with **[technology]** on **[location]** fulfilling **[human need]** made with a **driver/pedestrian/cyclist** in mind.

Bolded parts were filled into complete the sentence. People were given paper and markers to illustrate their ideas and encouraged to generate a lot of ideas. Ideas were presented for all and a second session was held to get deeper in selected ideas, which were chosen by voting. Participants were asked to vote one idea in each user group. The ideas that got most votes were chosen for in another round to develop them further. Groups were now rotated so that nobody had their idea from the first round. Participants were given options to present their ideas, either by sketching a scenario, playing the scene or by telling a story.



Next page: Figure 36. Slides shown at the beginning of the workshop to paint the picture about future Helsiki.

Ideas handled future traffic holistically. Shared cars, public transport and wide usage of city bicycles were ideated with a focus on safety and easiness of moving. Alternative ways of interaction were ideated, especially in cycling. It is a common problem that a cyclist has no possibilities to use their hands while cycling. Interaction would happen at dark times with light changes and the cyclist could talk to a street light pole to ask for help to navigate or in the case of emergency.

Concepts indicating how street lights could demarcate roads and avenues for autonomous cars versus human driven cars, or inform people of the type of vehicle from approaching were presented. Ideas for self-driven glass-roofed vehicles selling and growing vegetables absorbing light from street lamps at night indicated ideas of transition towards engineered efficiency.

Ideas were presented for all and second session was held to get deeper in selected ideas, which were chosen by voting. Participants were asked to vote one idea in each user groups. The ideas that got most votes were chosen to be in another round to develop them further. Groups were now rotated so that nobody had their own idea from the first round. Participants were given options to present their ideas, either by sketching a scenario, playing the scene or by telling a story.

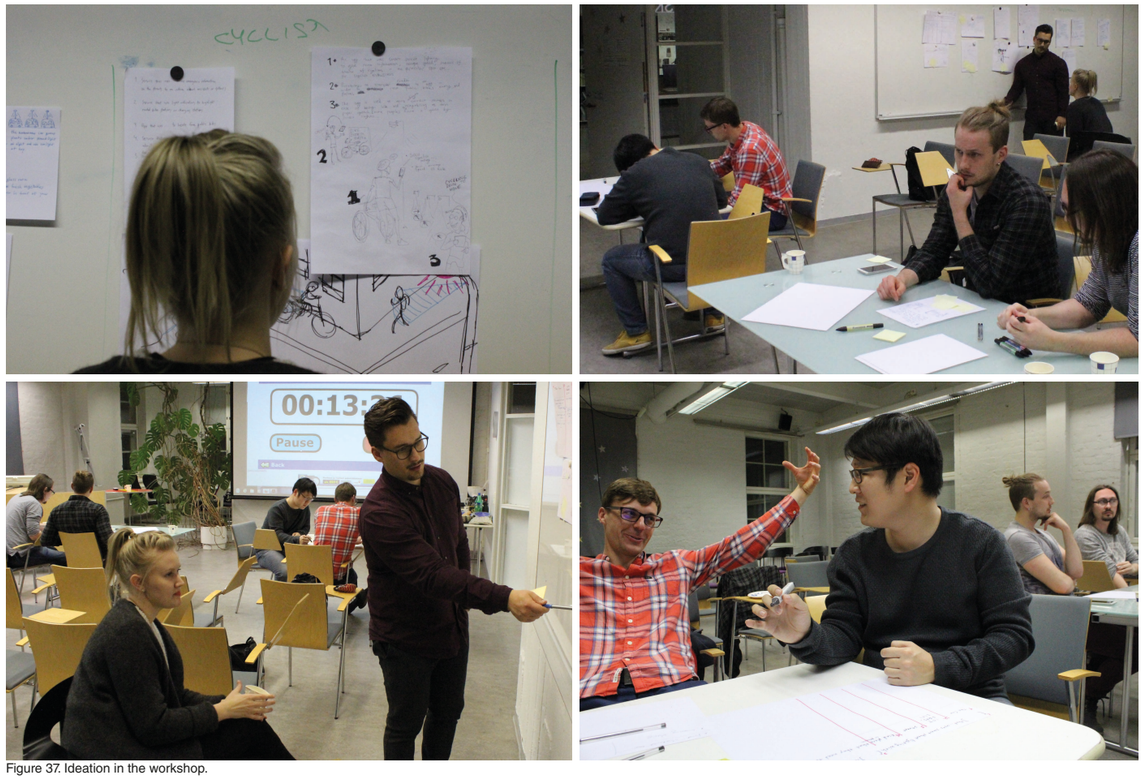
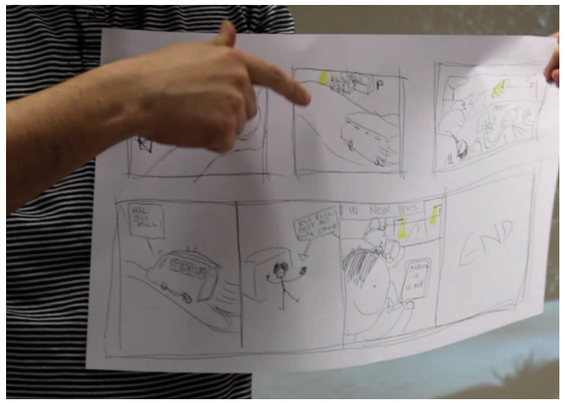


Figure 37. Ideation in the workshop.



Transportation service eclained with a visual scenario

Furher ideas abaut light functions for cyclists explained wiht illustrations

A. Janne jogging
In this is a scene, where Janne is out in a park jogging, having fun.

B. Janne falls, Olli is a light pole
Then, he slips and hurt himself really bad and can not move. Janne wants some help.

C. Injured calling for help
Janne: “Help me I broke my back”
Pole: “Hello this is the emergency number, do you need help?”
Janne: “I broke my back and I can’t move”
Pole: “Ok just a moment. There is nobody around you so I send an ambulance for you. I can see your location. we have the signal. just a few minutes. stay calm, I will stay with until the ambulance comes”
Janne: “Thank you”

Figure 38. Presentations in the workshop.

5.4.SYNTHESIS

In this chapter, I present combined synthesis of done user research. The ideas are guidelines and characteristics of issues intelligent street lighting can offer to the citizens in different contexts of use.

STREET LIGHT FOR DWELLERS

The city officials were concerned during the interviews that the dwellers could get annoyed caused by changing light levels caused by adaptive lighting. However, this was not mentioned as a concern by any of the participants. Some citizens compared the change of lighting to unnoticeable smartphone brightness adjustment. It is safe to say that prediction of citizens towards adaptive lighting is positive at least in this situation. Light poles on the streets also illuminate the interiors of private houses. As they do so, they could inform the dwellers inside the house what is going on outside. Discreet light changes are not noticeable for street users although if a dweller knows what to observe, the subtle interaction can be conveyed. Positive features of light reduce irritation of unintentional illumination of houses.

People were open to share their spare or produced energy from their energy storages. They always felt that they need to get some sort of compensation for the shared energy. Money was recognized as obvious choice but also as a troublesome option because of the economical situations. Options like discounts, vouchers for city's services and possibility to charge an electric car anywhere in the city were suggested as more light compensations for the city.

PUBLIC TO PRIVATE

In the Technology User matrix, I organized five urban lighting contexts, for drivers on the road, for cyclists, for pedestrians, for park goers and finally for the home. In such a sequence, there is evidence of a movement from public areas to private areas. In the solutions proposed by the participants, there is proof of a sequence from private to public. Ideas such as public lighting identifying parking spaces or a shared car from one's home were ideated. Also, ideas like how with the control of a park light one could rent space for a personal gathering or when a street light could provide a filter for taking pictures with mobile phones indicated the control of public lighting for personal use. This can be interpreted as an outward movement from private to public, facilitated by personal digital services through public infrastructure.

COMMUNAL USE OF PUBLIC SPACE

Citizens saw various usages of intelligent lighting in parks. There was a positive attitude towards the creation of special and temporal spaces with lighting, although if the lights were wildly changing, a possibility of a conflict of interest was seen possible. Lights could create for example atmospheric light for a romantic gesture like proposing. Temporal ownership of spaces could be set up with light, for instance for a picnic; space could be reserved by of adjusting desired lighting atmosphere and other people can see from the change of light that the space is being used by someone.

Then the concepts also indicated the potential for public lighting in community formation at a neighborhood level. For instance, the subtle change in street lighting as a form of feedback for collective energy management at a neighborhood level was suggested. Park lights nearby could indicate the presence of other people from a distance through its lights. This kind of feature can be a major feature of playgrounds or other places where social activity is a key characteristic. Potential community formation was imagined through public lighting in several different ways. Intelligent lighting could be used for measurement of the quality of urban space. People could rate their experience of space with local internet provided by Li-Fi. Rating data is a useful tool to evaluate public space, and the data can be used to develop urban spaces by the city. Anonymous Li-Fi data was seen more acceptable than surveillance or tracking.

SECURE EXPERIENCES

Security was considered to be an important issue in parks. In addition to calling for help in parks, people suggested that lights could help lost people, such as the elderly with memory problems. The idea could be extended to a service around old people's care homes that allow residents to move freely in the parks. Light could guide people with disabilities and create a feeling of safety and support independent moving outside.
People suggested many solutions where they could interact directly with the street light poles. These were applications such as guidance for a lost cyclist and emergency help by voice control. The light pole would either change lighting according to the need, for example, show a path or contact the authorities in situations where a person is unable to use a smartphone.

TRAFFIC

Lighting could function as a transition tech in the streets before autonomous cars are the majority of the mo-torized means of transportation. As autonomous cars could potentially make the roads safer with fewer ac-cidents (Lutin, Kornhauserm, & Lerner-Lam, 2013), the manual cars could seem a riskier option in contrast to autonomous cars. Autonomous cars will be connected to the smart city grid, and they will know the fastest route via a vast communication network. Lights could provide guiding and safety information for the human drivers as well. The same information could be communicated to human drivers by guiding them with light colors, blinking or the intensity of light.

In traffic, people would like to have less citizen control of lighting than they would like in other situations. In traffic, citizens want to be guided and organized, even on an overbearing level. Especially novice, unsafe and overconfident drivers perform worse in traffic than others (Craen et.al, 2009). Intelligent lighting technology functions in traffic were considered more distant and practical than they would be in a park for example. Also, more intelligent traffic was suggested in forms of intelligent public transport guide and car sharing guides. Public transportation guide could inform passengers at a bus stop if the bus is late or full. The bus would be connected to Li-Fi lamps, and the path to a better connection would be communicated with guiding street lighting. Guiding street light could also help a person to find a designated shared autonomous car on the street.

6. DESIGN VISION

Finally, it was time to use this data when data from desk research, preliminary research and user research all were collected. This chapter explains what things were focused on and how they led to the final part of this thesis, the design vision of street lights in the future.

6.1.PUTTING THE PIECES TOGETHER

As mentioned earlier in the chapter urban design, none of the stakeholders of city can work alone to make the city a better place to live in. The role as a designer can be seen as a connector of different stakeholders. The results came from citizens and they could only be implemented through city officials. The designer needs understand both stakeholders as well as the technology to be used.

The focus of this thesis was on user research and same research has been published in an academic design conference which was double blinded peer reviewed (Heiskanen & Acharya 2017). The focus in user research was partially done because of the importance of the user-centered methods in the city context and because they are common practices in my field. Professional interviews clarified the topic which was later focused in user research. The guidelines of today's decision making can be radically changed when the design concepts would take place, especially because a claim in this thesis is that users should have a more significant role in decision making.

The data collected from the user research shows some examples how citizens can be involved in city planning. The value of this can be seen in several various ideas that were generated during the research. Problems of the city can be solved with ideas and insights of citizens if they are given a change to do so. Also the assumptions of the city should be checked and justified by user research of citizens. In other words, the communication between the two should be more efficient and effortless. This research shows guidelines of citizen attitudes, wishes and needs. The methods and topics in the thesis can be scaled and modified for different situations and problems.

6.2.STREET LIGHTING IN THE FUTURE

In this chapter, I present my vision of future street lighting functions and services in three contexts of use; home, park, and traffic. The vision is based on the research done in this thesis and ideas generated by the citizens. Designers role is to go through all the ideas and suggest a combined vision of preferred future which serves as a sociocultural, collective vision of current times. The vision answers the (research) question of "What are the needs of the citizens for future intelligent lighting?", especially with chosen future technologies of autonomous cars, Li-Fi and energy storages. Further research could be done before implementing intelligent street lighting. Therefore this chapter shows a starting point and guides towards the development of future street lighting development. My hypothesizes that digitalization of urban technologies will continue in the future and I place the characteristics of the interaction between urban lighting and three upcoming technologies in such a context. My aim for highlighting potential characteristics is for those who wish to approach the design of new urban services, like for city administrators, service providers, and citizens.

The vision of connected, intelligent lighting system help to envision how a smart city could be realized in the future. This chapter shows how user data can be used in smart street lighting design with the possibilities of technologies and procedures for city planning.

The role of street lighting

Street lighting is an active and adaptive provider of light for every citizen. It connects private and public spaces and can make public spaces more personal by informing and adapting intelligently and interactively to citizens' needs.
It is a platform for connecting the all traffic around it and making it safer and traffic flow is more fluent. The street lighting analyses the different road users and adapts the lighting accordingly.

Connected light

Also, street lighting is an important part of communication network with connected systems. All streetlights have a Li-Fi feature which connect with users' personal devices on demand and cars. Light poles are not standing on the streets in vain in the bright Finnish summer months, since Li-Fi technology still works in dim settings that make it seems like there is no light on.

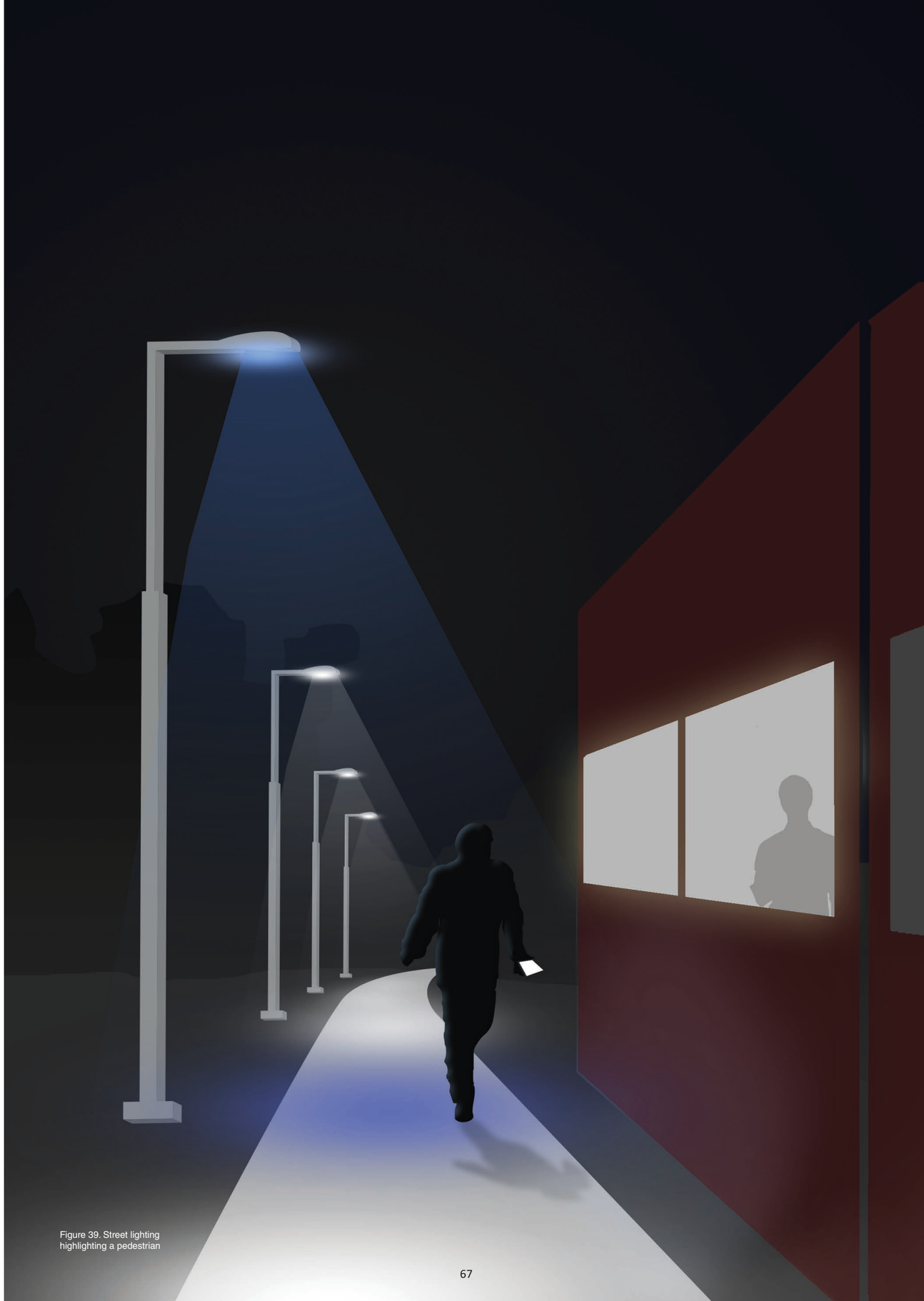


Figure 39. Street lighting highlighting a pedestrian

Li-Fi enables the possibilities of participative lighting systems. Users can interact with the lighting with their handheld devices. Especially in park environment, citizens change the light functions to reserve spaces and activate functions to support their activities.

Park
Voice controlling is activated when streets or parks become more silent. A voice command is activated on certain words such as “help” and “where.” Light does not collect voice data when it is not activated. Voice commands can help a person to feel safer by increasing light and guide to a right route and call help in case of an emergency.

The lighting of the urban environment generates secure and safe urban experiences for its citizens. An intelligent street lighting system around old people’s home could make it a safe zone by tracking the elderly residents’ strolls. If ever they were to fall, the system informs the elderly home employees. Also, individuals can adjust the light levels higher in case they feel threatened in their environment. No one is able to decrease the lighting levels under generally accepted levels when there are people in the parks.

Light for dwellers
Light control is open to be controlled by dwellers and their visitors in certain areas. Light informs dwellers of the situations of public street when it is required. Subtle changes of light color and brightness tell information to the ones who know to seek for it. Although, light never compromises the need for lighting of pedestrians and cyclists by adapting enough light for traffic.

Different areas are modified to have their own lighting characteristics. For example, areas with a lot of school children have strong lighting after the end of classes, and the lighting gets dimmer once it gets late. Citizens can form communities of lighting if they choose to. These communities help to create communal lighting that suits to the lifestyles and characteristics of the neighborhood. Energy consumption is shown in each group: individual control, community group and the city.

Citizens have a possibility to share their produced and spare energy with city. Especially the households who are producing energy themselves are allowed with the benefits from the city. Sharing energy allows people to get discounts on city services. Public transportation and car sharing are supported forms of transportation. Private usage of an autonomous car is charged more than shared car.

Traffic
Autonomous cars are connected to each other with Li-Fi street lights. By communicating with each other, they can choose the best routes and drive without stopping depending on other drivers, and thus avoid collisions.

Public lighting’s works as a transition technology between manual driven cars to autonomous cars. Manually driven cars use the same data as autonomous cars, but they get information through lighting. Like a GPS device today, a device on the windscreen collects data from Li-Fi and shows upcoming happenings, which are supported by street lighting. Street lights change color depending on speed and blink when an action needs to be done like a change of lane. Ambulances and police cars do not make as much noise as nowadays. However, traffic is guided to make way with lighting.

Collision warning functions also between cyclists, who are depending on their eye sight while driving. The street lights indicate cyclists the presence of others in blind corners. On intersections, street light indicates with subtle color whether it is safe to go on, slow or stop. Street lighting adjusts the lighting according the need of the traffic. In situation of less car traffic, the cyclists are informed of safer traffic situation with the lighting color changes.

Figure 40. Street lighting aiding cars

6.3.BENEFITS TO THE CITY

The city gets data directly from the citizens with the app and the sensor data. These data are not only quantitative but also progresses towards functional lighting systems. New services attract people to the city. People with different needs will move to the city because of the services, and this brings more tax payers, workers, intelligence and possibilities to the city.
The image of the city is citizen-centered and friendly, innovative, easy and green. These kinds of positive images help the city to keep and get more citizens to live in it. Especially Helsinki has an important role as the capital of Finland to represent the whole country. The national image is already innovative and environmentally focused. Especially the value of an innovative nation needs to be updated, or it shall not be credible.

Cities differ from companies because cities collect money from services that they provide to maintain them. The challenge in economy is that the budget is limited and cities have to be able to maintain services and attract people to move in and stay there. A challenge in cities is nowadays very often constant saving. New businesses open new possibilities for the city's economy as well as electricity savings brought by adaptive lighting.

New technologies, home energy producing and active citizen participation open the city new ways to providing services. Lighting becomes an active service provided by the city, and the citizens demand more from it.

Lighting will be seen more as a service than it is today and people are sometimes ready to invest in it. Normal lighting is received as a public good. Special occasions and the need for extra services are received with a small payment which is used for a city maintenance and development.

The city will provide more services than it does today. Autonomous cars can partially take over the role of public transportation and the city can provide transportation using self-driven vehicles and shared car services. The intelligent lighting systems need to be facilitated by city, and the citizens will appreciate new possible services available to them.

7.SERVICE CONCEPT

Based on this research, there is a need for citizen involvement in the context of future technologies that have an effect on street lighting. My suggestion is a service, which works as a tool for city to get ideas and evaluate the necessity of them by citizen participation. For citizens, it is a service that helps them to suggest their ideas and make them come to a reality.

The guidelines for the research done in this thesis can function as a starting point for developing an intelligent lighting system. Companies who are developing intelligent lighting devices and systems can be influenced by the research data provided by cities, which have a demand for a certain type of functions and services.

7.1.DESIGN DRIVERS

Design drivers work as parameters that define the orientation towards the final output. The following design drivers are for the citizen involvement service. These are created on understanding on user research and reflect my understanding on the topic.

Sometimes more effort is required in the process. As this thesis shows, there are methods to generate ideas among citizens. Although, only a few people actively try to make a change in their environment and reasons why most people are not taking part may vary. People might feel that they do not have the time or that their effort would not make a difference or they are not interested enough. There are signs of growing interest in active participation in social events in recent years, such as Ravintolapäivä (Restaurant day) and Siivouspäivä (cleaning day). Both examples have money involved which is not a reasonable asset if the city would arrange something to get people involved.

One point is that one individual can represent all user groups, even during one day. Therefore, the needs of an individual might change during a day as well. That is why street lighting functions need to work in right situations in a correct way so that it serves all the street users. Light might either work in certain areas in certain ways or it adapt to the users of the street and the situation.

People become active when the subject is interesting or personal enough. Street lighting may cause reaction a personal matter when it becomes different to what people have been used to, with adaptive or intelligent technologies. Possibilities of light doing something for the individual's needs is stimulating, and other people's ideas can be endorsed.
Even today the processes and decisions made by the city are open. However, they are rarely followed by citizens. One aspect of blaming is the form how those are presented. People do not go to city pages to follow what is done there unless they are irritated or passionate about a certain place, such as a home. A service that notifies the news of interest straight to citizens will help them to remain active.

Transparent

The decisions and process should be visible to citizens and everyone who is interested. Open decision-making would reduce the gap between municipality and citizens. When citizens get their voice heard, they are more likely to be more satisfied with their surroundings.

Engaging

The process should motivate people to take part in planning. The process should be effortless for individuals who want to take part lightly. The level of interest in participating should be flexible, since some people want to get involved more than others. Nobody should be pushed to take part more than they feel comfortable, although participation is encouraged.

Creating communities

The attitude in planning should be communal and demographic. If everyone would be just thinking about their own needs, there would be no progress. Service should bring people together and finding people with similar mindsets. Communal participation could reduce the inappropriate comments and irrelevant suggestions. Administration should be done but the goal should be that the service is run by citizens towards common solutions.

7.2.COLLABORATIVE URBAN LIGHTING SERVICE

The service is based on an understanding of the situation today in street lighting and the done research but suggest more speculative view how the communication between the city and the citizens could be. Again, research question being “How can citizens be involved in city planning,” the purpose is to suggest tools and methods for involving citizens with a service concept, which is done for a future where the intelligent street lighting is a major part of city infrastructure.

The city acknowledges the importance of user expertise in their own environments and collaborates citizens in ideation and street lighting planning. The main idea is to give people an opportunity to suggest a feature, function or implementation of a street lighting. If the idea is feasible, it can be implemented. Suggested ideas are visible to everyone in the service, which can be commented, regenerated and voted.

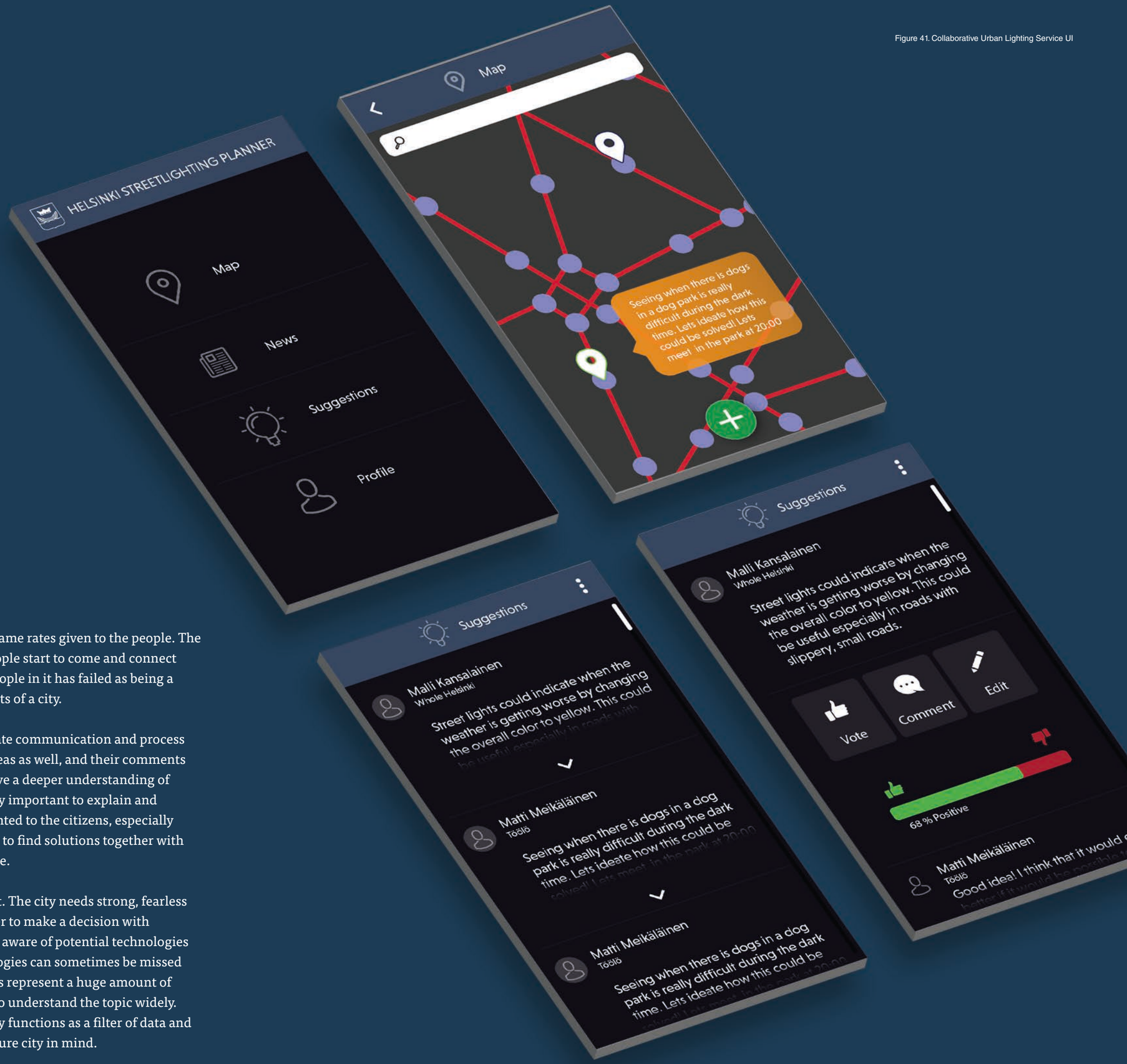
The service enables various different ways to create ideas and suggest them. There are possibilities to write an oral idea, organize an event to solve a problem or create alternative ways of presentation, such as scenarios and visualizations. A method kit is shared among active participant to facilitate sessions among other citizens. The kit contains rules and guidelines of the chosen methods.

The level of participation is optional for citizens adjust their interest and effort. An individual can choose to take part in minimum level by voting occasionally for suggestions or maximum by becoming a host for ideation sessions. A lighting protocol can be limited in small areas, like in a street where people agree on the light protocols and they benefit everyone in the area. This kind of communal areas will include more personal meetings, and the possible functions will be discussed outside the service as well. These meetings will help the decision making among the citizens and create a better bond between the community. If a valued idea is not economically feasible, citizens can take action themselves by crowdsourcing and networking with possible third-party stakeholders.

Implemented protocols are flexible. for example, if a need for lighting changes, a neighborhood with mainly elderly people can in time change to be more families with children, who will have different needs for the lighting. Changes start with the citizens, and they do not have to settle for functions that are given to them. A conflict between other people’s suggestions may cause reactions. In a situation where an idea divides many opinions, the conflict can be solved with further ideation and iterations to fulfill the needs of both parties. A vote can be taken in troubling cases, but the goal primary is to find solutions that would satisfy most people and the process would be open to everybody to react. In other words, the planning process is transparent.

IInstalled lights are rated with the service as well with a suggestion for lighting. Another type of rating is done about public places of the city to let city official know how well they have succeeded. The app is used to rate public spaces, like parks. Citizens rating can be seen by other citizens and the city officials. The usability rate of the parks is counted to the city to rate and

Figure 41. Collaborative Urban Lighting Service UI



evaluate the service and success of the park as well with the same rates given to the people. The difference between a place and space is the people. When people start to come and connect with space, it is called a place. For example, a park with no people in it has failed as being a place for people and stands for a space between other elements of a city.

A city's role in the service is to develop good ideas and facilitate communication and process among all the stakeholders. City officials can comment on ideas as well, and their comments are shown differently since their role is different and they have a deeper understanding of the technologies and process is more profound. It is especially important to explain and communicate well why certain solutions cannot be implemented to the citizens, especially when the idea is popular among the citizens. City officials try to find solutions together with citizens to find solutions for more convivial city infrastructure.

The city still makes the final decisions and discuss the budget. The city needs strong, fearless leadership to make new ideas come true. It is, of course, easier to make a decision with convincing data and insights from citizens. The city has to be aware of potential technologies and present then to citizens. The possibilities of new technologies can sometimes be missed when they are studied only from one perspective, and citizens represent a huge amount of different opinions. It is important to involve many opinions to understand the topic widely. Nevertheless, it is important to be able to make decisions. City functions as a filter of data and realizer ideas provided by citizens with the strategy of the future city in mind.

8.CONCLUSION

This chapter shows my thoughts on the process and done research. I also present how I see what could be done in the future by other with similar interests and by myself.

8.1.REFLECTION ON DONE RESEARCH

In general people were open and enthusiastic about having intelligent street lighting on the streets. Although there were concerns about the conflict between other street users, people saw potential benefits in new technologies and the attitude was mainly positive.
People are interested in these future technologies, such as autonomous cars, Li-Fi, energy storages and they suggested similar ideas spontaneously in different contexts. For example, sharing an autonomous car was not presented in energy producing scenario sessions, but it came up by testers as well in the workshop. One insight was that people want more renewable solutions, even if there is no direct benefit to themselves. This was seen in ideas of energy producing scenarios and attitude towards adaptive street lighting.

The views of experts and citizens were not always same in street lighting. City officials concerns about conflict of interest of the street users are not going to be solved by ignoring the technology. Citizens suggested different forms of ways to reduce the conflicts between other people. User-centered and urban design can create approaches and systems that will work for citizens without conflict or annoyance.

Overall, the research methods succeeded to generate novel ideas to intelligent systems. Not all the suggested ideas were feasible themselves however they could be used as a starting point for systems that can make streets more safe, convivial and functional for all. The goal of this study was to show how citizen participation can generate ideas that are relevant to peoples' everyday lives and still be novel ideas for the future. Used user-centered design methods did succeed to produce over 150 ideas in different contexts. The user-centered design does give valuable insight into urban systems even though the technologies are novel and there are no yet experiences of them. Intelligent street lighting could create more value for the city and its citizens. Safety, community, healthcare, well-flowing traffic and better utilization of public places are few possibilities that citizens envisioned that intelligent lighting could provide.

8.2.RELEVANCY OF THE WORK

The vision of the future street lighting function well as an example of the outcome of a user-centric project in this scale. This thesis works more as a showcase of user involvement in urban service design than ready solutions for street lighting services. More user research is needed for the definition of the services and service models, possibly with other research methods as well. It is relatively easy to say that the solutions could be reality in the future since the optimistic way of seeing the future enables one to imagine that almost anything could be possible. Future cannot be predicted, but quoting Abraham Lincoln, "the best way to predict future is to create it," makes sense when it comes to the possibilities of the technologies. Although, alternative technologies can take over if an invention is doing something better than technologies presented in this in this thesis. The technologies are not the most important aspect but instead, what they can do for people.
This thesis implemented citizen imagination on the future technologies. This way it is possible to reflect the user values and needs of today and move towards solutions that meet the needs. Future solutions might not be exactly the ones that users suggested, however, they highlight the issues that citizens want to be different from today in the future.

Development will not happen without the impact of the voice of the users of today. The thesis works as an example of how the city could implement design methods and user involvement in planning urban lighting and decision making.

8.3.NEXT STEPS

This work would be beneficial to be read by city officials and smart lighting developers to get an idea how citizens would like to make the future of urban environments and show ways how to involve citizens in decision making and visioning of the use of future technologies.
The service would help citizens to be part of the decision making process. More user research should be done on the topic to gain a holistic understanding of citizens' views. During this research, I was able to gather important user data, since limitations of resources and time, I felt that more research should be done in the future to tell what are the needs of the whole city. The implementation of the service will take time and effort but can it can be scaled down in case of short budget.

There is a need for wider research of the citizens, especially within a scope of the street lights for everybody. If the research was done for a specific user group, such as elderly people with memory problems, the needs could have been mapped with certainty. Therefore, the research to gathered user data needs to be scaled. One option is to hire more designers to do research or scale research methods so that they will work with less work. The methods themselves work as ideation and need finding tools, which would be needed to be scaled so that bigger number of citizens could participate in development in the future. The designer is still needed in the process, although a variety of ideas was collected from citizens. The designer works as a facilitator who provides tools for user research, collects them together and transforms the material into design (Vaajakallio & Mattelmäki, 2007).

The city planners who are in charge of decisions on of urban street lighting need to be reached again to validate the need and benefits of user-centric design methods in this context. The research in this thesis is a scratch of the surface of data and ideas that can emerge from the citizens of Helsinki but shows great potential of user participation. If the role and functions of the lighting are going to be changed, the role of designers is going to be important as facilitators of user involvement and enablers of design activities. Development and testing of the service should be discussed with the city officials and relevant stakeholders. With the user-centric methods and research and strong involvement of the citizens, the city can take a step closer to a truly smart city.

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B. APPENDIXES

OLLI MARKKANEN

Q: WHAT IS THE DECICION STRUCTURE IN HELSINKI
Helsinki has made a clearance of needs about lighting in the city and in that the pressure is in electricity consumption because it is a big part of operating expenses.
In Helsinki LED project was decided how Helsinki turn into LED era in two ears but first there was a clearance that showed that it would have cost 100 million euros plus bureaucracy costs.

New calculations are going to be made in September. we have also made other calculations, such as about replacing lamps, which have an own igniter in the lamps. Partially EU is going to ban lamps with high power next year and the availability is getting harder.
if we would change everything to LEDs now, there would be 10 year payback time. Major thing is that LEDs are getting better all the time. A magical borderline which is being spoken is 200 lumen / Watt. After 4 to 5 years we are going to be there.

ARE THE FUTURE ISTALLATIONS GOING TO BE DONE BY LEDS?
Yes, already we are installing only LEDs. Maybe In some super big motorways led would not work necessarily but there is going to be lamps with high power. LED started out with special solutions, like with integration to switches, small floodlights and signages. There is a lot to do in that field. Handrails have been lit with small LEDs but surprisingly big problem is that the strength of support when it can take 100 kg and bend 1 cm. Its not that easy to realize. There has been thought about light in benches as well, light could turn on when someone stops there to read for example. The power supply can't be where person is touching.

IS THERE SOME OTHER ADAPTATION IN LIGHT NEEDED?
There was a competition of lighting which we arranged and the winners was a light that adjusted the light temperature depending on a time of day. This has been studied in schools, that children wake up in cooler light and at some point get even aggressive which can be answered by turning the light warmer again. Outdoors we had studies about preferences of light temperature have been made before LEDs. What I have noticed is that younger people prefer cooler temperatures whilst older prefer more yellow light. By dynamic lighting we could provide light that would please everyone. Problem is that this has not been studied! I have asked Liisa Halonen there could be more studies about this. Color rendering index is another thing. Good color rendering looks fantastic to lower color rendering lamp. Good index lamps are available only in certain temperatures at the moment.

Q: HOW DO YOU SEE LIGHT AS A SERVICE?
There are lots of calls from people suggesting thesis about lighting as service. They are about bank, credit and hidden debt which is not possible in Helsinki. you would sell the light as a service and pay by saving the price of the electricity. That is a very common business model and there is nothing new in that. Lighting as a service does not work.
Back in the day you could get a ESCO project supported by government (An energy service company or energy savings company (ESCO or ESCo) is a commercial or non-profit business providing a broad range of energy solutions including designs and implementation of energy savings projects, retrofitting, energy conservation, energy infrastructure outsourcing, power generation and energy supply, and risk management.) We did not use that because we were in Helsingin energia and there was money for investments. You would be married to this company's lights... There are these support programs. All the LEDs have dimming feature, and if there isn't, there should be. There is this midnight dimming technology. There are shortcomings such as playgrounds. There are street classes and such but maybe they should be thought more in case-specific. Nowadays a kid is picked up at five from outside when it is already dark. we have not studied to define the lights to fit the situation.

ARE THERE TESTING ENVIRONMENTS FOR DIMMING?
At the moment, streets the acute thing because the sensors' cost is so high that the savings of the energy from lights less that 50W do not pay themselves back. But other reason is safety, like in kindergartens light could be turned on when there are junkies on the yard in there after the place is closed. I think that we need now solutions for the small environments that are in the scale of humans, not architectural scale.
other thin is lighting in the critical places like in pedestrian crossings. It does not really work in Finland really, because we are using the standards given to us. Other problem is that people are not crossing the road on pedestrian crossing but where ever. Strong dimming is not safe in pedestrian crossings. There is also dimming need of animals, like bats and European nightjars. there is even turning off needs for this reasons. On ball fields, there is a need for remote control, so they would be lit only when there is someone playing there. User research shows that people are satisfied with the lighting in Helsinki.

COMMENTS ON CONCEPTS
Power to the people
The problem here is that there is different power-distribution network in houses and outdoor lighting. This could work in England, where everything is in same grid.
Thunder could be a problem because they destroy LEDs and in this case, they would go to the households. It wouldn't need to hit the house itself but these are long networks and it can induce electricity and bang it there. Law says that there must be power grid monopolies. if there are lights on the streets then nobody can come to change things there, does not matter how much they would pay.
with electric cars, this would be realism because cars battery can be used like this. But how to discharge it so that it is profitable? there is a basic problem here that one KWH costs 10 csents trough battery but basic electricity costs 3.8 cents per KWH.

ISMO ARMINEN

Q: could you give an overview about Vantaa's public street lighting?
A: There are 40 000 spots in Vantaa and around 20% of those are LED spots at the moment. The price of the LED lamps has come down so much that it starts to be a competitive option. From the city's 30-year life cycle thinking's point of view, LEDs are paying themselves back from savings in that timeframe. It is better for residential streets compared to yellow light produced by sodium-vapor lights because LED's light is closer to natural white daylight color.

Q: How has Street light changed historically in Vantaa?
Nowadays the trend in new building areas has been to put more than just technic lighting, visual aspects have taken control with the design of the pylons with different colors and shades, adaptive lighting and light pollution needs to be taken on consideration. It is going towards a situation where the light is there only there when it's needed, and LED's provide better control.

The budget is a challenge if there is a lot of special objects, it is away from a basic lighting of the city. Money is always the problem; you always wish there was more. There is always the basic budget and if something "extra" is wanted to build that costs more.

Q: HOW IS THE INFORMATION OF BROKEN LAMP RECEIVED?
A: We have an information system, which is used to control all the lighting centers of the city. It works through a mobile network, and the lighting center is working wirelessly. Then we can see the main power of every lighting center and they are measured in real time. If the light spots start to die out, it is seen in the change of the power unit. We don't have light spot specific indicator system but it would be possible with LED technology.

LEDs can be controlled as desired and every light can be controlled individually. But at the moment the most sophisticated system is in Kivistö, where there is a light specific control system. It can be controlled using a computer and individual a lamp can be selected and can be edited with individual operation curve. This is still so small scale in Vantaa so we don't really do this, though. Kivistö might be in the future a place where there will be this kind of expedient lighting, there is all the preparedness. If in the future there will be light control there, during the silent hours all the pedestrian crossings could be brightly lit and other lights would be dimmed. This wouldn't be an active system, though. Next step would be adding motion sensors to lights. These testings are going on in Kivistö as well, next to railway station there is bicycle lane with this system.

Q: IN WHICH SITUATIONS LIGHTS CANNOT BE DIMMED?
A: Lights need to be brighter where there is a lot of traffic, intersections and pedestrian crossings. This is all because of the safety reasons. It does not serve a purpose to keep all the lights on full brightness at 2am. in October when there is no one on the street. Longer lifespan is received for lights by dimming, energy is saved and light pollution is reduced.

Q: HOW IS THE EVALUATION OF A STREETLIGHT BRIGHTNESS DONE?
Traffic engineers need to evaluate streets together with a person who knows it from a safety point of view.
Vantaa is planning to be test streetlights with motion sensors and we should gather feedback from people. There is a bus traffic in the area, so we could ask feedback from bus drivers about their experience of adaptive lighting when they are driving there. They are driving there all around a day and it is important to know if it disturbs their work and does the light make them feel more alert in the intersection area. The thing to take on consideration is that the change of brightness level of the light may not be too flashy. It depends on which kinds of steps are the lights adjusted. Q: How is the evaluation of a streetlight brightness done?

Q: WHO IS CONTROLLING THE DIMMING AND BRIGHTENING?
A: We start adjusting the brightness using computer calculations at first and there is no-one actively controlling the brightness. It is part of my job to follow if the light is pleasant and if there is any feedback. The number of LEDs is being increased and there will be feedback from the residents if the light is disturbing or glaring, so the lights can be dimmed to make the environment enjoyable. Still, as long as the light is on, people are normally satisfied and it that is all that matters to them.

Q: HOW IS THE INFORMATION BETWEEN ENERGY COMPANY, CITY AND ENERGY TRANSFER COMPANIES?
A: There are electricity consumption meters in every lighting center from which energy company charges the municipality. We don't follow that data here in the municipality that much but of course we check the bills to see if consumption is coming down or not.
We believe that there is going to be energy savings because of usage of new technology, such as the LEDs. Of course, we are thinking about the economy of the municipality and try to invest on energy efficient solutions. City decides about things regarding energy consumption, like dimming, since it is the owner of the lighting network. In some cities, they have problems with small budgets and they try to figure out ways to save the energy. For example, some cities turn off lighting during the summer because there is an order of saving money. Luckily Vantaa hasn't gone into that.

Q: Why is there not even more LEDs utilized?
A: We are replacing the mercury-vapor lights because of the EU directive and the other thing is that the lighting network starts to be in such a bad condition that the lights need to be changed anyway. Even though the investment is a bit bigger on LEDs, they pay themselves back in few years.
There has been a discussion about reducing sodium-vapor lights because EU is constantly tightening the energy efficiency directives. This would mean that these lamps would need to be changed to LEDs as well.
Nowadays when we are building new streets we are using LEDs by default. But LED has its own defects. For example, they are not accepted to be used on bigger roads and highways. This is because of the long distances of the lamp posts and high installations. LEDs can't produce enough high luminance levels for this kind of situation. To gain that luminance level LED power would need of increased so much that the consumption would not be competitive to gas-discharge lamps and LED lamps would not pay themselves back.
Other thing with LEDs is that the control of the light beam and the glare is disturbing. When you take highlight from a small point, it comes out very sharp and bright. So it is not that pleasant and even compared to gas-discharge lamps. But LEDs are still being developed.

Q: WHY NOT MORE ADAPTIVE LIGHTING?
A: Adaptive lighting comes through LED technology and when the LED network is expanded there is going to be more possibilities. If there is money and needs, we can start to control the light more. At the moment we program this dimming diagram to LED lights. When it is switched on its on full brightness. In some streets you we program lights to dim earlier a bit. These programs depend on what street class does a street need to have.
So if we would start to control individual lights that would mean that there would never be 100 % brightness there. Or maybe from the switching on until 20:00 or 22:00, when there are people moving there. Default brightness could be 40 % brightness and when needed it could change to 100 % or maybe to 70 %. There would be great energy saving opportunities. City would look like quite dark when there is nobody moving.

We can envision that when there is an ambulance on duty the lights could brighten for it on its path. Anything is pretty much feasible, some neighborhoods residents could be given the code for street lights for a park where they could play with the light.

Q: HOW MUCH INTELLIGENCE IS THERE IN A LED LIGHT SPOT AT THE MOMENT?
A: We can take information in newest models about power values and temperature, where we can tell if the light is functioning. that is all we need at the moment. Sensors can be added in case they are needed.

Q: DOES CITY CHANGE LIGHTING FOR SPECIAL OCCASIONS ON REQUEST?
A: Yes, we receive them quite a lot. At the moment we can't do much but turn the lights on or off. But when there is going to be more LEDs we can dim them. We can also give the code for organizer and lights can be controlled by them own. We serve the people of the city and I don't see why this kind of service couldn't be done.

Q: IS DEMAND RESPONSE UTILIZED?
A: If there is a major interference or shortage in electricity the authorities can make an order for cities to turn off the lamps to save more electricity. In that sense, it is working in Finland, but I don't know if this situation ever happened. If this kind of situation in Finland would happen that Finland could not buy electricity from the international power grid, we could start cutting the expenses. Cities do not make these kinds of plans together; the information is moving in Fingrid.

Q: HAS VANTAA HAD CITIZEN ENGAGING STREETLIGHT PROJECTS?
A: I don't know if in Kivistö had these kinds of plans in the beginning, maybe in some parks people could have effected on the environment. Overall people do not get involved in city planning, that would mean that we wouldn't get anything done. Professionals are doing the job.

So if we would start to control individual lights that would mean that there would never be 100 % brightness here. Or maybe from the switching on until 20:00 or 22:00, when there are people moving there. Default brightness could be 40 % brightness and when needed it could change to 100 % or maybe to 70 %. There would be great energy saving opportunities. City would look like quite dark when there is nobody moving.
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Q: Did Vantaa had engaging streetlight projects
A: I don't know if in Kivistö had these kinds of plans in the beginning, maybe in some parks people could have effected on the environment. Overall people do not get involved in city planning, that would mean that we wouldn't get anything done. Professionals are doing the job.

JUHANI SANDSTRÖM

Head of Public lighting in City of Helsinki Public Works department

Aalto arts, there has been more and more interest in lighting. It brings good added value as a light as a service, not just as technology. This is the thing I have tried to get through almost for ten years here, that we have to get started from that aspect.
We have these old engineer “fortresses” like construction office of Helsinki where stubborn street building engineers have two principles against service design ; first, design is completely daft and they are not serving anybody. They think that they know what people need.

COULD YOU GIVE AN OVERVIEW ABOUT HELSINKI'S PUBLIC STREET LIGHTING?
Renewing goes in cycles. Ten years ago there was not too much talk about energy efficiency. It was not essential, the environment was not being destroyed, it was not recognized like it is now and the price of the electricity was not a problem. EU-directive of 2009 where there was defined a ban of certain awful products and the access to the market. Mercury-halide lamps were first to go and there was time until the year 2015. We had a situation of having around 85000 lamps which out of 60 000 were mercury-halide. Before that situation was completely desolate. We changed almost every lamp and got decent fixtures in energy efficiency terms for that understanding of that time. Then we saw, knew and regretted that the LEDs were coming and we knew we could get with them but we couldn't wait because the year 2015 was coming too fast.
Now we have very energy efficient lamps now, we were able to drop many tens of percent's and it is in quite a good condition compared to the last situation. Right after we got this done, then during last year LED's started to show their power. Politicians wanted a calculation on if every lamp would be changed to LEDs. We counted that it did not make much sense since we have just changed everything and there is quite a new fixture and pretty energy efficient as well, so we should use that for some time or at least as long as it makes sense and change them then. Then we did a decision in principle that we change the worst 10 000 lamps to LEDs quite fast and we would do all the new construction with LEDs mainly. After the installation of few thousands, we started to think about the controlling possibilities. We have been part of different research projects where we have been researching different kinds of intelligence to these lighting. There we have been thinking new thoughts how everybody would benefit it there was some intelligence in street lighting. The main theme is to make two-way communication for every light where there is data control, feedback information and sensor information. This communication can be used every data control and by this payer can be involved.
Pilots are being started and we are thinking what is reasonable, how much light can be, is wanted to be controlled and how is it controlled. We are talking about that we should be able to control amount light by an amount of users. We don't have information about how much can we dim the lights according the users without people being hit by cars. Another thing is weather and environment condition. How could we standardize the amount of light so that we are taking into account the environment condition and we could light just right amount. The technology exists, but it does not last outside as long as it is hoped to do. What we hope is that someone would start to think about what people would really need. We shouldn't tease anybody in the sake of energy savings and it should be pleasant.
We have tests where for example bicycle lanes are controlled how much on advance is the light on, what is the speed of change, how much can it be dimmed and how the residents of houses nearby experience the light. It is infuriating to watch the light through a window when the lights are brighten up every now and then. these things nobody has studied yet.
I have received suggestions about 20 times that we should use some sort of brighter, adaptive, blinking or colored pedestrian crossing light. This comes always from laymen and sales person. When I have searched research, I have found controversy results of the effects of security. Many of the research points out that the security is decreased when the light is well lit or highlighted because people do not cross the road on pedestrian crossings. People loosen the awareness and cannot look out for the cars. These kinds of things need to be researched before they are put into operation, we need the knowledge of traffic psychologies and research results from the influences, the assumption is not enough.

WHAT KINDS OF PROBLEMS OR CHALLENGES DOES CITY HAVE REGARDING STREET LIGHTING?
Biggest is that the systems are not working. Everything needs to be sustainable and reliable. It is easy to plan some fancy technology on a lamp but we must be able to maintain the functions in practice for 30 years with maintenance interval of several years.
Conditions are really fierce and products have to be tested to be able take that. What is also unfortunate is that vandalism is a big factor and another thing is car crashes and other accidents. When a pillar is fallen and the technology is that kind that data is moving from pillar to pillar the data cannot pass.
Is there something that could be done better?
Probably a lot. I wished that we would stick to the appearance of the light, color and how it is lit. There has been a lack of guidelines and the installations have been done a bit randomly. That makes a quite disorganized result. We have done quite a lot of user research in past years. We have asked what is the preferred light temperature and the peak was always the same 3000 Kelvin.

Q: HOW IS THE INFORMATION OF BROKEN LAMP RECEIVED?
Another thing we do is that we use an astronomic clock to dim the lights during night hours. A profile is set beforehand there. Then we have determined for different kinds of streets how it goes, that two hours before computational mid-night it's dropped to 20 to 30 percent and then morning hours, when it is that silent hours' time, it is dropped to 40 to 50 percent. It is a preprogrammed and there is no control system, but the profiles are set for a single lamp.
Preprogrammed profiles are done completely for energy saving reasons. That is the only light controlling we have now. With the projects, we try to figure out how could we put these into operation in a way or another.

HAVE RESIDENTS GIVEN FEEDBACK ABOUT DIM LIGHTS?
No, I think that they don't even notice it. We can take even 50 percent's off and users do not even notice. I just hope that it does not have an effect on street security. Fortunately, here there is so little accidents that we cannot even see the effects in statistics. Feedback is mostly about the qualities of light, especially from glare when shines to someone's bedroom window. These are mostly individual cases.
Another thing that gave us a lot of feedback was the color of the light. When we started to change mercury-halide lamps to sodium-halide lamps I could tell where the installers were moving when people started to complain about yellow lights. One thing is also this hanging Y- lamp in the center. It is supposed to lit also the facades, which makes the city look like a city. This causes the light to glare in people's homes and we cannot do much about it. Unfortunately, someone suffers about them time to time.

IS THERE GOING TO BE MORE ADAPTIVE LIGHTING
I'd like to see it that way. Especially taking into consideration lighting conditions, so we could get a standardized light. Nowadays metering is made by the worst condition and everything is lit by it. Smart control by the traffic flow could be good. It could be also that the time of a day could be enough, we know that in an early morning there are not many people and less light is enough. But whether we dare to go to that situation that we dim the lights when sensors show that in basic night time there is not much movement. It does not feel like feasible in big scale.
Parks and walkways are a different thing. we have a lot of these forest paths where lights are on even if there is no-one there. If we could dim those lights there could be big potential. There is an economical problem there though because the modern devices are so efficient. if we are using an 18 W lamp and we could get half of it off, we would save few euros, maybe ten euros annually. And the sensor that is needed cost a hundred euros for every lamp so this technology would not pay itself back. In these projects, we have been looking for a solution how we could get information of the users in a reasonable prize. The positive problem here is that lamps consume so little energy that saving becomes expensive.

ARE THERE ANY TESTING ENVIRONMENTS IN HELSINKI?
We had a short stretch of road in Malminkartano, in Siltamäki we are building the sensor side and in Mustikkamaa we are going to have a new pilot in autumn regarding the dimming. All of these are light traffic sites and we haven't started to play in the traffic because of the safety issues. First, we try in walkways and more distant sites.

ARE THE DECISIONS MADE BECAUSE OF ECONOMICAL OR ENVIRONMENTAL REASONS?
The environment is the reason, in my opinion these things would not be profitable on economic reasons at all. It's hard to save in money because the price of the electricity is so low. Compared to other countries, lamps are expensive though.
Political guiding is giving us energy saving goals. The city has its own agreements that are transferred to us and construction office has its own. We have had for few years a goal to decrease energy consumption by 2 % each year even though the city is growing. Lighting is a big consumer of energy and no one is asking how much it costs, so environment issues are ordered for us regardless the economic saving goals.

DOES DEMAND RESPONSE HAPPEN?
Not really, we have some turn on orders, so we don't turn every lamp on the same time so we don't get any foolish peaks in consumption. But it does not effect on load otherwise than momentary consumption.
We are doing a plan for big demand peaks or for transferring problems so we have been planning how would we dim and turn off lamps so energy could be used for more critical things. It has not been implemented yet.

HAS HELSINKI HAD CITIZEN ENGAGING STREETLIGHT PROJECTS
We have done these questionnaires about different technologies and preferences. Collaborative design hasn't been utilized. We have been trying to find information in other means and we have been doing it how we have imagined what users want. Collaborative design is too hard.

DOES HELSINKI AIM TO BE A SMART CITY IN THE FUTURE
I wish and believe that we are going towards that direction but it is a long way. We have been discussing what data is available and all sorts of wise guys talk all sorts of open data which all the information storages are full of but any advantage takers have not shown up, even though we have been trying to get them. Data could be used in street maintenance and parking control and we had all sorts of ideas. But every stakeholder that we tried to contact either did not care or told us that laws are blocking the ideas.

WHAT IS THE WANTED INFORMATION FROM SENSORS?
Amount and speeds of different vehicles and pedestrians. The surface of the street could be analyzed, whether its slippery, wet or frozen, which all demand in different kind of maintenance. Electric car charging points with the information if the point is occupied.
We are ready to offer platforms for mobile networks or to WLAN etc. We have been quite open about the possible co-operation but I'm always warning about an unsafe place of installation because the pillars are down every now and then.

HENRIKA PIHLAJANIEMI

BACKGROUND
Architect and lighting designer

WAS THERE AN ORDER FOR THE RESEARCH?
There was a project called Adaptive Urban Lighting - Algorithm aided lighting design -research project which I was working for so dissertation became easily from that project. Adaptive lighting was topical already in the year 2011. I see the future of the smart lighting good, lighting controlling is coming and there are possibilities to get added value in those. For my work, there was a new research question how lighting can be designed and what methods can be used. How user can be involved and how experience can be taken into the design process.
In Oulu, there were visible pilots that were interesting for the city of Oulu so from they have given more orders for lighting design where users are wanted to be part of the process.
Sencity project has six pilots around Finland. Biggest challenges have been finding right service providers and products and to have real needs in lighting. Somebody has to pay those services.
Cities realize intelligent lighting gladly in different levels. What do the lighting react to is one aspect and another one is how much it saves energy? LEDs save energy themselves already but how we get to that point that the lights have some added value in them require various other technology in the lighting and also the payers.
Base stations should be added on the field but if there're no service providers, we will not get autonomous cars with connections. Or should be so, that the cars should be service providers? it's a certain "which came first, the chicken or the egg?"-situation. Also, the problem is that people are not used to paying for anything, so what is the business model is one of the questions. Business research and know-how are lacking even though technology and users are involved.
How do you see the usage of street lighting in the future?
I see it being a multidimensional thing and I make of it trustfully. I believe that we are moving on from the on-off switches to control depending user numbers. Of course from the side of energy savings, there is the point but also there is own aspect from usage, experience, and maintenance side. In the future, it could be that we switch from the energy savings to creating added value.

WHAT ARE THE VALUES OF INTELLIGENT LIGHTING FOR USERS?
Energy savings have been seen as an important value. When the environment is dim but when a person comes around lights turn brighter people understand that energy is being saved. Brand value comes from that city Oulu has been branding itself as an intelligent city so it was seen positive that lights were intelligent too.
One important value is atmosphere value. Of course, it depends on design but in our pilots, we have had this atmospheric lightning which has been seen really positive that with lighting it is possible to create atmosphere and experiences.
One aspect is that how lighting can support security. Security is a complex thing, for example, one of the pilots we have tried to create optimal lighting that would not affect negatively on lighting but energy savings would be as high as possible. Feeling of safety consists of many things, is environment lit, is there something beautiful and what is the context of the place. I believe that with adaptive lighting it is possible to support safety.
There're many ways of doing adaptive lighting. On motorways, light does not have to follow a single car necessarily, but a number of cars can be counted and the data of the conditions can be analyzed to control light of the lighting. For every place, there is own optimal lighting. On the other hand, there are motorways in Germany which are completely dark because it is thought that cars produce lighting themselves.

HOW DO YOU TAKE IN CONSIDERATION ON PEOPLES DIFFERENT OPINIONS OF THE SAME LOCATION?
We have in one pilot quite unusual lighting, it highlights beautiful sights and has effect lighting on the paths. People have given a lot of positive feedback and it has increased the usage of that park. In addition to that, there's been negative feedback and comments of that there is dark because it is the same lighting that it has been. It is also having more contrast in the lighting and darkness. During winter it's not a problem because snow reflects the light. It is hard to please everyone because people have their own opinions. Lighting design has been trying commonly to equalize lighting, and the end results are not particularly interesting. The benefits and possibilities of smart and adaptive lighting that lighting can be modified afterward and use themes that might annoy someone. Also, if people are taken in part of design process, they are more engaged with it. The attitude is them more personal and it has seen more positive. Also, more local data is received that is not known before.

ARE ANY SPECIFIC USER GROUPS TAKEN INTO CONSIDERATION IN PLANNING?
In our recent pilot, we took elderly and young adults as two groups of testers. Elderly represent a group to whom technology is not familiar and young are more excited about the technology.
CITIES RELATION TO SMART LIGHTING?
Cities have come really excitedly with to this projects, they have really big interest. Lighting aspect is easy for them, that is what they want to develop. They want that energy saving and also In Lahti builds an impressing whole for the world championship on the harbor. Other than just basic lighting is wanted, there's going to be controlled RGBW lighting game and light art. Cities have a lot of expectations. But the threshold is that who uses, administers and gathers the data and how is it used for business. We are going towards smart cities but lighting is easy thing to control, data is not.

THE ROLE OF THE TECHNOLOGY COMPANIES?
Different parties have their own projects, where own products are being developed. Valopää, for example, is developing smart system and control. Also, the devices have been tested. Some pilots are technology driven and some are user driven. Personally, I see that from user driven model comes better business and results.

WHAT WERE THE USER REACTIONS AND FEEDBACK
In the dissertation, we studied the communication of light. In park context the acceptance of far more unusual proposals than it would be in street context. Interesting thing was that people learned, experienced colorful profiles surprisingly positively, it was found refreshing. The value has seen a color spot in a snowy environment. Also that the light is never the same was seen positive and it can change according to the time of the year or an event was a positive aspect.
People had strong opinions of the colors and they crossed over each other. few of the scenarios was especially disturbing or was a danger for movement.
Motives to controlling are surely play and activities where there is a clear context like parks. The design is always contexted bound, different situations require different solutions.

COLLOBORATIVE URBAN LIGHTING SERVICE