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Envisioning the future of public lighting with citizens for upcoming technologies.

Olli Heiskanen*a, Karthikeya Acharyaa
aAalto University
*Corresponding author e-mail: olli.heiskanen@aalto.fi

Abstract: Today’s cities yearn for new technological infrastructure to become cities of tomorrow. Sensor based intelligent street lighting by promising energy and financial savings are being provisioned to be a functional alternative to conventional street lighting. But involving citizens’ participation in planning such new urban infrastructure and its services is far from simple. In our project using constructive and user centred design research methods we engaged with city officials and citizens as users of public lighting to ideate the potential of future technologies interacting with public lighting. Through citizens’ participation, we explored possible applications in visioning urban environments with autonomous cars, Li-Fi and domestic energy storage, and how these upcoming technologies could have an impact on public lighting. With a synthesis of this process we present five potential urban environment characteristics when upcoming technologies reflexively interact with urban outdoor lighting.

Keywords: Smart street lighting, Constructive Design Research, Citizen

1. Introduction
Outdoor lighting forms an essential component of public infrastructure in any global urban context. It has been undergoing technological transformation since its inception. Currently, intelligent lighting systems that use adaptive technology are being 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. Some of benefits of the technology are reduction in energy consumption, reduced light pollution (Pihlajaniemi, 2016) and tackling disturbance of circadian rhythms of animals and plants (Burnett, 2011). Studies on use of adaptive technology for public outdoor 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). 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 intelligent lighting have shown that through such a technology, citizens could engage with public infrastructure and enjoy unconventional lighting in a public environments (Pihlajaniemi, 2016, p.148). The promise of this new technology and its deployment has its concerns. Testing the impact of such public lighting within large cities in multiple contexts is...
complex. While urban technologies impact everyday lives of citizens, involving them in shaping such future public infrastructure and widening its application through participation is far from simple.

Within the scope of our research, we wish to address the facilitation of citizens’ participation for visioning how upcoming technologies may have an impact on public lighting. For this we frame intelligent lighting of smart cities in the context of three future technologies, of autonomous cars, Li-Fi and energy storage through household batteries. Autonomous cars could change the way we see the role of the public lighting of roads. With Li-fi, people and vehicles could communicate with street lights accessing sensor data from the environment. Household batteries could be connected to the street lighting grid and cities could rent storage or buy energy produced by citizens’ private infrastructure in exchange for benefits. Thus with such upcoming technologies, changes to outdoor public lighting as a technology is anticipated. We 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, we engaged with city officials and citizens in creating future urban visions for intelligent lighting and its interaction with the three upcoming technologies. By analyzing the proposals we present characteristics and potential for citizen led urban public lighting of the future.

2. Constructive Inquiry

We believe that 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 our project takes a path through design. Our approach to design research is both constructive (Koskinen et.al, 2011) and user-centered (Keinonen & Jääksö 2004). We create design concepts with people and document them or hand over prototypes to them and follow their responses in interaction as inquiry. Towards such a goal our research presents a number of design-led procedures. We began with design based interviews (Bergström et.al, 2009) with city officials to gain an understanding of mind-sets and attitudes of the decision-making bodies in city administration. Informed by its analysis, we then proceeded with a round of design based fieldwork and ideation workshops with citizens as users (Koskenen et.al, 2011. P.69-82).

Our inquiry began with desk research on the topic on public lighting to generate initial design concepts. This research also led to a broad understanding of public lighting and the need for viewing it in relation to its context with other technologies. The initial design concepts were utilized to initiate a discussion about intelligent city lighting systems with experts who were city administration officials. The analysis from these sessions informed further inquiry with users of future technologies. This led to narrowing on three upcoming technologies and identification of relevant user groups. The analysis from this phase led to generating a Technology-User Matrix. We identified five relevant user groups, their relationship to the upcoming technologies and their contexts. For these groups we then carried out three design based procedures; a design workshop, situated testing of an application mock-up, and a user based scenario building session that made citizens imagine urban lighting and its interaction with upcoming technologies. With this we generated a corpus of citizen involved future conceptual scenarios of the city. The synthesis from these concepts is presented as potential characteristics of public outdoor lighting interacting with three upcoming technologies.
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3. Viewing public lighting with the city administration

3.1 Interviewing city officials

We began the inquiry with expert interviews, after a desk research. The interviews were undertaken to broaden an understanding of the city administration’s decision-making processes within the scope of public lighting. For design led inquiries, experts can provide valuable perspective before starting to design for people of a selected group (IDEO, 2015, p.43). We involved three experts on public lighting from the city administration to gain an understanding on attitudes of the decision-making bodies from the city. Based on our desk research, twelve concept visualizations of citizen-centric services for public lighting were made and these were utilized as a central tool within the interviews.

Professional interviews were held both in the cities of Helsinki and in Vantaa. The three interviews were with a construction manager of outdoor lighting at city of Vantaa and with the heads of outdoor lighting for the city of Helsinki and Vantaa. The interviews began with questions about planning and decision-making considerations in cities for public lighting. Based on the desk research, questions were posed about the limited studies on connected, intelligent lighting systems within large urban contexts and the challenges of conducting such studies. Questions pertaining to the city administration’s approach to research on this topic were also asked. Then the city officials were shown concept visualizations of lighting services and their possible functions as future urban infrastructure services (Fig. 2). The visualizations as mild provocations to the city officials let them express the possible problems and further potential of the design concepts (Keinonen & Takala, 2010, p. 25). With concept visualizations our aim was to create a shared foundation for understanding and explore design alternatives for the existing context (Bergström, Mazé, Redström, & Vallgårda, 2009).
3.2 Public outdoor lighting: Inferring the official view

The interviews with the city officials were transcribed, coded and categorized. This data was gathered onto sticky notes and converted into a full wall affinity map. Notes were pasted on 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; Koskinen et al. 2011, p. 76-79). From the insights that emerged from the affinity mapping we present selected three relevant categories.

From Economical To Ecological: Standards And Policy Driven Decisions

Data from the interviews with the city administration indicate that city budgets, industry standards and policies shape the planning and decisions of large public infrastructure such as city lighting. Structural influences such as current ecological policies become drivers of decisions. City administrations are also interested in energy efficiency and savings so new upcoming technologies such as adaptive lighting influence their decision-making. While rapidly evolving technologies with sensing and digitalization of energy systems afford more choices for new service and business models from city infrastructure, finding and involving new and interested stakeholders into these processes are far from simple. The city administration interviews indicated that upcoming technologies can generate savings, for maintenance, through energy efficiency and innovative services. Although to mitigate the initial high costs there need to be relevant and feasible service offerings involving multiple stakeholders including everyday users of the infrastructure.

Gap In Citizen Involvement

The next take away from the interviews was that user studies and research of different lighting technologies across different contexts were not widely undertaken. The tests are done through questionnaires and surveys to evaluate and check already installed technologies. Decisions are made with the view that the choice of the administration are based on current standards and what people need, thus engaging citizens further need not be useful. Two officials stated that with respect to upcoming technologies they did not know what people needed. Also, from the interviews it was interpreted that public lighting for people as a technology is normalized and further service design need not always be seen as valuable.
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**Citizens And Contexts**

Thirdly as an investigation of people who experience public lighting daily, the affinity mapping from the city officials interviews helped categorize five different citizen user groups with their contexts. This categorization was useful to firstly finalize the list of upcoming technologies and then map their reflexive relation with the various contexts of outdoor public lighting.

*a)* Drivers, *b)* cyclists, *c)* pedestrians were the first three categories of users on the roads with traffic context.

*d)* Park goers as the fourth category was for public lighting in urban recreational areas.

*e)* Residential dwellers the fifth category was about how issues with street lighting could matter for residents at a neighbourhood level and to an extent when citizens dwelled within their homes.

Based on the initial desk research three upcoming technologies, that of autonomous cars, Li-Fi and domestic energy storage was mapped onto the above user-context categories. The hypothesis was that the advent of autonomous cars could have implications on the use of public lighting for the first three categories, Li-fi could be useful in the fourth category for park users and the for fifth category of residential dwellers, domestic energy storage technologies could be made to have implications for suburban neighbourhood outdoor lighting. To clarify such hypothetical potential we decided to gather everyday citizens’ opinions. So after the process of the inquiry with the city officials the research moved onto engaging with citizens.

4. **Design Visioning with citizens**

4.1 **Technology User Matrix**

To delve further into the five user categories and their contexts we undertook took a quick survey. It involved asking twenty people to evaluate the possible functions of smart lighting in situations where autonomous cars, Li-Fi and household energy storages would be used from the perspectives of the five user groups. We did this with willing participants from within the context of a design school. The upcoming technologies were introduced and explained as necessary to the participants and evaluations were carried based on a combination of upcoming technologies and the mentioned contexts. In this evaluation of combinations, a Likert scale was used (Cohen, Manion, & Morrison, 2013), where in the scale, one represented disagreement and five for a full agreement. The survey also provided an opportunity to discuss potential ideas for adaptive lighting with its relation to the upcoming technologies in the five different contexts. Data from the survey were analyzed by comparing combinations of the contexts and the user groups.
The results (Fig. 3) showing attitudes of people towards the relevance of upcoming technologies onto public lighting is presented above as the Technology User Matrix. As indicative in the figure, the participants indicated that there were implications for drivers, cyclists and pedestrians and their experience of street lights if autonomous cars were on roads. Then the Matrix indicates that the experience of pedestrians and park goers could be impacted if street lights were streaming information through LiFi technology. It also shows energy storage through domestic batteries 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 coming sub-sections of the article will concisely discuss the three design procedures undertaken with a mixed set of participants.

4.2 Ideating Workshop For Future Avenues

This procedure addressing the first three categories of user contexts, of drivers, bicyclists and pedestrians was in the format of a design workshop. Our goal was to discuss with citizens the future of public lighting in the age of autonomous cars and connected traffic. Six participants with a design background 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 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 the political, economic, social, technological and ecological issues (Johnson & Scholes 2001) concerning Future Helsinki. Then a task of fill in a word was given to the teams.

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

With this task participants were encouraged to illustrate a large number of ideas. These were then distilled where participants were asked to vote for one idea from each group. The ideas that got
most votes were chosen to be in the next round. The ideas and groups were then mixed from the first round making people to work on each other’s ideas. In the final round participants presented concepts that were video-recorded and the visual output were scanned. The final design concepts were treated as data for future analysis.

Figure 4. Participants sketches from the workshop.

4.3 Situating A Lighting App Within A Park

The next design procedure’s goal was to explore people’s experience of public lighting in a park environment. Prior desk research (Pihlajaniemi, 2016) had directed at the themes of safety, amusement, and community for this context and we heeded to 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 addressed the above themes (fig. 5). The simulation was through mobile screen transitions so as to trigger an imagination for the functionality of park lights. The application simulation as a design inquiry referred to Situated and Participative Enactment of Scenario (SPES method) as a tool for envisioning ideas of services in their natural setting, where an idea can be proposed by the user or the designer within a use context (Jacucci, Kuutti, & Ranta, 2000). This procedure was carried out in a park with nine participants. People were first introduced to control of smart lighting in public spaces and possibilities through Li-Fi technology. Then they were taken below a light pole in the park and handed out a mobile phone with the mock up application. Having 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 what 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 discussions were audio recorded and documented through photos and videos as necessary. The discussion and the proposals by the nine participants as data was analyzed for this procedure.
4.4 Co-Creating Services For A Home Selling Power

The third design procedure was for the residential dwellers context. The focus here was on two aspects. Firstly what citizens thought about sharing and selling their energy for their neighbourhood street lighting and secondly how do they perceive the benefits because of selling or sharing their energy to the city infrastructure. This procedure too 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. Scenarios were made with with co-creation sessions using sketching and visual prompts. First people were introduced with an idea of producing energy in households through distributed solar systems and batteries in their homes. Then they were told of the possibility that a part of that energy could be shared to the public grid which could light the immediate neighbourhood. Next a set of visuals were presented as a day in the life of a person living in a suburb with adaptive smart streetlights. The participants were asked to imagine what the smart
street lighting could do in particular situations of their choosing from the visuals. The session was
carried out with the visuals alongside empty sheets of paper (Fig. 07). Participants were asked to fill
in by writing or drawing what their neighborhood street light could do if their homes energy storage
contributed to the lighting of their street. People first ideated on the benefits of sharing their energy
with the public infrastructure. They were also suggested that the system could allow a possibility to
control public street lighting. For these contexts the participants generated ideas and functions for
the street lights through sketches.

In the second part of the procedure people were asked to look at another scenario. There each user’s
street light usage would be tracked and they would be charged by the city for that instead of taxes.
The idea was to provoke people to think about behaviors and values differently than from the first
part. This raised the discussion on public and private energy production and usage and citizens
privacy. It also opened new discussions of control and demand of energy sharing. These discussions
were recorded and the papers with writings and drawings were documented for further analysis.

Figure 7. Scenario building sessions with visual prompts.

5. Synthesis
In this final subsection, we present our synthesis of the participant generated ideas and design
concepts from the three design procedures. This is a limited and selected position based on the
analysis generated from the data with twenty five participants from the three workshops. Since there
were a large and diverse set of suggestions, ideas and concepts (>150) we do not present those
instead we present a grounded synthesis. Our aim is to highlight the potential characteristics of
urban outdoor lighting when it reflexively interacts with three upcoming technologies, automated
cars, Li-Fi and domestic batteries. Our position hypothesizes that digitalization of urban technologies
will continue into the future and we position the characteristics of the interaction between urban
lighting and three upcoming technologies in such a context. Our goal of highlighting potential
characteristics is for those who wish to approach the design of new urban services, such as city
administrators, service providers and citizens. For the final analysis we organized all the concepts
from the participants based on the three design procedures. We followed the affinity mapping
procedure again and coded the concepts up to three levels. In the final level there emerged five main
interrelated categories. These we present as the potential characteristics of future urban public lighting.

5.1 Transition Technology
The analysis inferred public lighting’s potential to be of transitional nature. Concepts indicating how street lights could demarcate roads and avenues for self driving cars versus human driven cars, or inform humans of the type of vehicle from further away were present. Ideas for self driven glass roofed vehicles selling and growing vegetables soaking in the light from street lamps at night indicated ideas of transition towards engineered efficiency.

5.2 Secure Experiences
There were also a number of ideas and concepts that indicated how the lighting of the urban environment could further generate secure and safe urban experiences for its citizens. For instance how an intelligent street lighting system around a radius of an elderly care home could make it a secure zone by tracking the elderly resident’s strolls and if ever they were to fall the system could inform the care home authorities. Then how the street lights could indicate to cyclists the presence of others in blind corners or also how instead of traffic lights street lights could guide future traffic safely indicated public infrastructure for secure experiences.

5.3 Informing Lightly
Since the larger topic was about public lighting the ideas and suggestions utilized its central characteristic as a medium to inform. The suggestions and concepts utilized dimming, brightening and change in colour and hue as a mode to inform when people were outdoors. The concepts imagined informing a move beyond personal devices and onto the public infrastructure. We saw this as an extension for communication, anticipating to ‘lighten’ the mode of information in the public realm.

5.4 Making Community
Then the concepts also indicated the potential for public lighting in community formation at a neighbourhood level. For instance the subtle transformation of street lighting as a form of feedback for collective energy management at a neighbourhood level or where a neighbourhood park through its lights could indicate the presence of other people from a distance indicating how social a place is were concepts indicating that the participants saw the potential of community formation through public lighting.

5.5 Public-Private-Public
In the Technology User matrix we 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 the public outdoors into the private realm. In the solutions proposed by the participants there is evidence of a sequence from private to public. Ideas such as such as public lighting identifying parking spaces or a shared car from one’s home, or 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. We interpret this as an outward movement from private to public facilitated by personal digital services through public infrastructure.
As a synthesis our article has presented five potential characteristics for urban environments when upcoming technologies reflexively interact with public outdoor lighting. Our aim of presenting these is for facilitating further relevant services for the future urban environments. Building on prior design methods our research approach has been constructive and user centered with the aim to further designing urban experiences with people. Through this process, for the age of converged technologies we indicate the need for considering reflexivity with upcoming technologies and for taking this issue to people and designing with them. Our next step is to take these findings and procedures to the city authorities and indicate the potential of engaging citizens for new urban services with design approaches.

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About the Authors:

Olli Heiskanen Masters of arts student of Collaborative and Industrial design in Aalto ARTS, Helsinki. He has a bachelor’s degree in industrial design.

Karthikeya Acharya undertakes energy research through design practice. He has a doctorate in design research from Aalto ARTS, Helsinki, a master’s in interaction design from DA+IDII in Milan and a degree in architecture from Manipal University, India.

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