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mySMARTLife

Deliverable due date: 30.11.2018 – Month 24

D3.10 Design and implementation of adaptive lighting concept

Transition of EU cities towards a new concept of Smart Life and Economy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Project Acronym	mySMARTLife		
Project Title	**Transition of EU cities towards a new concept of Smart Life and Economy**		
Project Duration	1st December 2016 – 30th November 2021 (60 Months)		
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Lead beneficiary	Free and Hanseatic City of Hamburg, HAM		
Contributing beneficiaries	Deutsche Telekom AG – T-Labs, DTG		
Task description	Task 3.8: Public lighting improvements – SMART LIGHTING [HAM] Subtask 3.8.1: Adaptive lighting. HAM will develop a solution to install 40 lighting assets for adaptive lighting along the new planned bicycle route. The task comprises the design of the solution and interaction as well as control of the foreseen components (LED lights, camera, WI-FI and monitoring equipment) and 10 poles with charging infrastructure for EV.		

Date	Version	Author	Comment
08/11/2018	1.0	HAM-BGD	First draft of the Table of Content
12/11/2018	2.0	HAM-BGD	Chapter 1 and 2
19/11/2018	3.0	HAM-LSBG	Chapter 3,4,5
22/11/2018	4.0	HAM-BGD	Chapter 6, Language correction
22/11/2018	5.0	HAM-BGD	Interim Version submitted to Cartif
23/11/2018	6.0	HAM-BGD	Chapter 5, new Map
27/11/2018	7.0	HAM-BGD	References, Figures, Tables, Corrections
27/11/2018	8.0	HAM-BGD	Upload on SharePoint
28/11/2018	9.0	DTG	Chapter 4.8 Picocell
29/11/2018	10.0	HAM-BGD	Final version

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Abbreviations and Acronyms

Acronym	Description
mySMARTLife	Transition of EU cities towards a new concept of Smart Life and Economy
BUE	Behörde für Umwelt und Energie (in English: Hamburg Ministry for Environment and Energy)
BWVI	Behörde für Wirtschaft Verkehr und Innovation (in English: Hamburg Ministry for Economics, Transport and Innovation)
DIN	Deutsches Institut für Normung e.V.(in English: German Institute for Standardisation)
DWD	Deutscher Wetterdienst (German Meteorological Office)
EIP SCC	European Innovation Program Smart City and Communities
HHVA	Hamburg Verkehrsanlagen (in English: State Agency for Hamburg Transport Infrastructure (analogue translation))
imHLA	integrated multifunctional humble lamp posts
LSBG	Landesbetrieb Straßen, Brücken und Gewässer (in English: State Agency for Roads, Bridges & Waters)

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1. Executive Summary

The main objective of the mySMARTLife project is the definition of an innovative Urban Transformation Strategy to present best examples to the follower cities to support them in developing their own approach towards a smart city. In this context, street lights are currently being re-examined as a possible platform for new sensors and assistance systems. In addition, it is expected to achieve energy savings in public spaces with new LED technology. The aim of this deliverable is, to provide an overview about the Hamburg specific approach to integrate new smart lighting concepts in the existing lighting infrastructure.

It shows that main challenges in the implementation of this technology are in the areas of responsibility and future maintenance of the new sensors, as well as unclear data ownership for the collected data.

This deliverable is close connected to deliverable D3.11 “Humble lamppost”, which focuses on the exchange of conventional lighting with LED lighting. Here, the focus lies on the deployment of new sensors and lighting control systems at the new planned bicycle connection in the development area in Hamburg-Bergedorf. Therefore this deliverable depends also on the implementation of Action 32 “New bicycle connection”. Due to a legal litigation, the implementation of the bicycle connection is delayed. However the concept is completed and presented hereinafter.

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2. Introduction

2.1 Purpose and target group

This deliverable provides an overview about street lighting in Hamburg and a technical description of the practical implementation of the sensors at the planned bicycle connection in Hamburg Bergedorf. It contains a technical description and the description of the planning and decision making process for interested follower cities and professional audience.

The present deliverable is structured as follows:

Chapter 3 shows the general background and framework in which this intervention happens, like the existing street light concept in Hamburg, the types of lighting in Hamburg and the evolution of the intervention. Since it describes the general conditions of smart lighting in Hamburg, this chapter is the same as part 3.1 - 3.3 in deliverable 3.11 “humble lamppost”.

Chapter 4 shows the technical description of the chosen sensors, here the chapter 4.2 “LED Light” is redundant to D3.11 “humble lamppost”.

Chapter 5 shows the plans for the implementation of the action, the local conditions and the description of lighting concept for the new bicycle path.

Chapter 6 completes this deliverable with the conclusion, including a review of the main challenges and an outlook on future developments.

2.2 Contributions of partners

The following table shows the main contributions from participating partners in the development of this deliverable.

Table 1: Contribution of partners

Participant short name	Contributions
HAM	Chapter 1,2,3,4,5,6
DTG	Chapter 4.1 and 4.8

2.3 Relation to other activities in the project

This deliverable is allocated in Task 3.8 “Public Lighting improvements” and describes the results of subtask 3.8.1 “Adaptive lighting”. It is connected to deliverable D3.11 “Humble lamppost”, which focuses on the exchange of conventional lighting with LED lighting. This deliverable provides an overview of the deployment of new sensors and lighting control systems at the new planned bicycle connection and in the new construction area along the old industrial channel “Schleusengraben” in Hamburg-Bergedorf. Therefore the results of this deliverable are also depending on the implementation of Action 32 “New bicycle connection”.

Table 2: Relation to other activities in the project

Deliverable Number	Contributions
D3.11	This deliverable provides the description of the exchange of conventional lighting with LED.
D3.2	This deliverable provides the description of the baseline report of Hamburg and the simulation models of the building stock, energy systems, transportation and urban infrastructure.

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3. Background and Framework

The City of Hamburg is determined to see digitisation as an opportunity by using its potential for greater efficiency and thereby to improve the economic power and quality of life for Hamburg's citizens. The fundamental goal of the Digital City Strategy is always one of the following: the use of technologies to improve service quality, the more efficient use of resources, to foster the quality of stay in the city and simultaneously the reduction of pollutants.

It is also a goal, to create the basis for the possibility for companies to develop fields of innovation, in which they can try out new options and technologies and develop them to market maturity in pilot projects.

Against this background, public lighting offers an existing infrastructure that can be used in the smart city for new services and it creates an opportunity for intelligent street lighting.

Smart lamps are characterised by the fact that the individual light point not only fulfils the function of the lighting, but also offers additional services for citizens. An increase in the scope of functions offers the linking of services and makes further services possible.

LEDs are the ideal luminaire for intelligent street lighting. The properties of the defined light direction and the variations in luminous intensity and light colour is a main improvement compared to former illumination.

By introducing a smart street lamp concept, it is intended to save energy and maintenance costs and reduce CO^2 emissions. Here not only the investment costs have to be considered, but also the subsequent operating costs.

The project is not intended to be an end in itself. Therefore not all technical possible sensors were built on the lantern masts, only those, from which an increase in value is hoped in this range.

3.1 Street light concept in Hamburg

As a service provider to the authorities and agencies, the State Agency of Roads, Bridges and Waters (LSBG) is responsible for the realisation and demand-oriented maintenance of technical infrastructure facilities in the Free and Hanseatic City of Hamburg.

This includes the planning, design, construction, project control, maintenance and operation of main and federal roads, coastal and inland flood protection, water bodies (except federal waterways), infrastructures (including bridges, tunnels, walls, locks, barrages and pumping stations), traffic signal and traffic telematics systems, public lighting and development measures of overall urban significance. Since the summer of 2018, all public lighting tasks have been the responsibility of the 100% municipal subsidiary "Hamburg Verkehrsanlagen GmbH" (HHVA).

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As part of mySMARTLife, the LSBG is working on the two subprojects "Humble Lamppost" and "Smart Street Lighting" with the aim of providing citizens with additional services via public lighting infrastructure.

The Hamburg lighting is conceived on the basis of various planning principles. Regional legislation, e.g. “the Hamburg Roads Act” (so called *“Hamburger Wegegesetz, HWG”),* the “Hamburg rules and regulations for planning and design of urban roads” (so called *“Hamburger Regelwerke für Planung und Entwurf, ReStra”)* or the “Law on Green and Recreation Facilities” (so called *“Hamburger Gesetz über Grün- und Erholungsanlagen”*), define street lighting in public spaces.

Further basic principles are collected in the national regulations DIN 13201 Part 1-4 "Lighting technology for street lighting" (DIN, 2005), the "Guideline for the installation and equipment of pedestrian crossings" (R-FGÜ, 2001) and the "Act on measuring point operation and data communication in intelligent energy networks” (so called *“Gesetz über den Messstellenbetrieb und die Datenkommunikation in intelligenten Energienetzen, MsbG”*) which all apply nationwide. The "Measuring Point Operation Act" (MsbG) is an essential component of the “Act on the Digitisation of the Energy Turnaround" (so called “*Gesetz zur Digitalisierung der Energiewende”*) and reregulates the topic of measuring point operation and measurement new. It has been in force since 2nd of September 2016 and has been implemented in October 2017.

In order to reduce the planning effort required for a lighting system, the lighting requirements are transformed into geometric sizes, which means that the light point height is corresponding to the width of the traffic area (standard cross section). The selection of the optimum luminaire-mast combination is based on the cross section of the road and the assessment of lighting, electrical, operational and economic aspects. Depending on the function or traffic volume of different road users in the area to be illuminated, different lighting classes must be distinguished in terms of the brightness of the illumination.

In order to make the operation of public lighting more efficient, Hamburg has introduced standard masts and standard luminaires, therefore around 80% of the systems consist of 5 types of luminaire and 5 types of pole. The municipality operates a total of around 125,000 luminaires, 135,000 lamps and 105,000 masts. With this number of lamps, it is more economical to replace series lamps on a regular basis than to replace defective lamps individually.

The road traffic sets the standard for the intensity of lighting. The street lighting in Hamburg is centrally switched on via a computer. Several measuring points distributed over the entire city area measure the brightness. If defined brightness values are fall below or exceeded, a switching command for switching on or off is automatically sent via the power grid. If 3 of the 6 measuring points reach the corresponding switching thresholds, the corresponding switching command is sent. The street lighting is switched by audio frequency ripple control (frequency 283 1/3 Hz, amplitude 2% of the 50Hz voltage). Different switching commands are sent depending on the function of the lighting (street lighting, pedestrian crossings, fog area and illumination).

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3.2 Types of lighting in Hamburg

As described in chapter 3.1 above, for operational reasons only a small number of luminaire types are used in Hamburg. In 2007, the European Union decided to reduce energy consumption by 20% by 2020 (compared to 1990). The climate protection target for 2020 is therefore: 32.5 GWh/a. The City of Hamburg has steadily improved its energy consumption for public lighting by introducing new technical components and increasing lamp efficiencies (lumen/watt) and by replacing conventional and low-loss ballasts with electronic ballasts. Thereby it was already possible to save energy in the 1990s. From the 2000s onwards, luminous traffic signs were increasingly dismantled. Instead, traffic signs and traffic equipment with retroreflective foils were used.

The following table shows the energy consumption of public lighting over the last years.

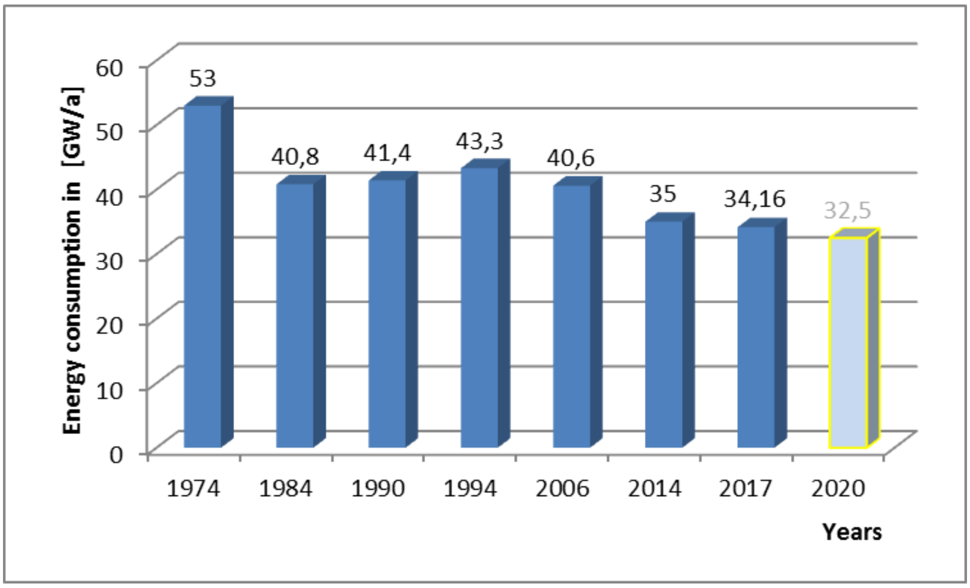

Figure 1: Energy consumption of public lighting (own representation)

In Hamburg different light sources have always been in competition with each other. The goal: to gain a lot of light with little effort (costs).

The beginnings of public lighting were realised with oil lamps, followed by petroleum and gas. Then new types of electric lighting developed: first arc lamps, at the beginning of the 20th century until the mid-1970s incandescent lamps in their various stages of development. Since 1950, fluorescent lamps have been used in public lighting. High-pressure mercury vapour lamps were used from the 1930s onwards and low-pressure sodium lamps from the mid-1970s. In the 1980s, the last gas lamp in Hamburg was switched off (Verg, 1984). The last high-pressure mercury vapour lamp was replaced in 2010.

More than 10 years ago, the first LED was installed as street lighting. In the beginning, the technical developments of the components were not yet so mature that an exchange of the new technology

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between cities would bring economic and ecological advantages. Hamburg therefore decided to wait until the technology had developed to an extent that the conversion would pay off in every aspect.

The technical development of the LED opens up new possibilities for street lighting. At the moment LED lighting is used more and more often in public lighting as it becomes more cost-effective. Today not all new street lights with LED built for economic reasons.

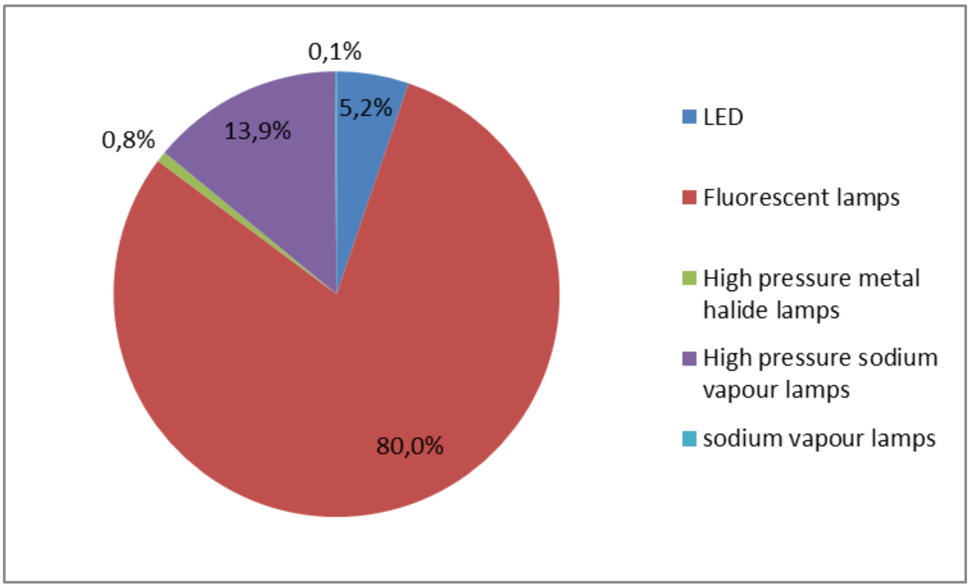

Figure 2: Overview of lamp types in Hamburg 2017 (own representation)

3.3 Project evolution

The work on the smart lighting intervention started in spring 2017 with a small internal workshop between the mySMARTLife partners HAM-LSBG, HAM-BGD and DTG about possible equipment and sensors. At this stage different problems like the question of responsibility for sensors and data, as well as technical problems regarding the metering and legal aspects have been identified and discussed. After the concretisation of the plans for the lighting along the bicycle path, several meetings with other authorities have been hold.

Figure 3: Smart street light in Munich (own source)

The first meeting has been organised with the Hamburg Ministry of Environment and Energy (BUE) to discuss the possibility to integrate environmental sensors at a lamp pole. The ministry made clear, that the air quality is monitored by the Hamburg air measurement network with continuous measurements at stationary observation containers. The sensors

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for this measurement network are calibrated and harmonised to specific national standards to fulfil the “39. Federal Emission Control Ordinance” (so called *„Neununddreißigste Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes“, 39. BImSchV*) and it is not possible to install these sensors in a lamp pole because of high technical requirements.

A meeting with the German meteorological service (Deutscher Wetterdienst, DWD) in December 2017 ended with the same conclusion, that the sensors for weather forecast are defined by international standards and in general placed away from buildings, traffic or other influences. Therefore a weather sensor at a lamp pole is not a meaningful solution.

Much more promising have been the meetings with the Department for Bicycle Traffic of the Hamburg Ministry for Economics, Transport and Innovation (BWVI) and with Hamburg Verkehrsanlagen (HHVA) which have been very interested in new LED lighting and sensors to count bicycle traffic. An agreement was made, to integrate sensors for bicycle counting in a lamp pole as part of bicycle traffic measuring network, which is currently under construction for the whole City of Hamburg.

Furthermore, partners from HAM-BGD, HAM-LSBG and HAM-LGV made in spring 2018 a study trip to Munich, where experts of the H2020 Project “SmarterTogether” (Horizon 2020, Grant Agreement no. 691876) presented the local solution for smart lighting. It has shown that the City of Munich has taken much effort to develop and tender a new lamp pole type, for the integration of smart components in the lamp pole, while the approach of Hamburg is to develop the existing portfolio of poles.

After all these preparatory talks, the responsible partners decided to focus on implementing sensors related to the measurement and the improvement of bicycle traffic, because here is a realistic use case after the project given.

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4. Technical Description

In the cityscape, light poles are present everywhere. Due to their regular locations and permanent energy supply, they are a good prerequisite for a multifunctional digitisation infrastructure. With the appearance of mobile, wireless (radio-based) internet and the increasing possibilities of sensor technology, they offer the possibility, to realise “the Internet of Things" everywhere in the urban area.

Street lighting is therefore the forerunner for a future integrated digital city infrastructure that can link different components and services or provide information.

The following chapters describe the use cases envisaged within the project and the possible additional services for public lighting in Hamburg

4.1 Din-Spec

The German Institute for Standardisation e.V. (DIN) is a worldwide independent standardisation organisation. Through its cooperation with industry, research and society, the institute contributes to the development of standards for innovations to market maturity and the development of future fields.

The Smart City Standards Forum of DIN investigates in new upcoming topics due to digitisation. One central aspect is the required infrastructure, based on a variety of sensors across the city and the necessary information and communication technology. Following the Action Cluster “Integrated Infrastructure” of the European Innovation Program Smart City and Communities (EIP SCC), which is separated in “Humble Lamppost” and “Open Urban Platform” DIN partners, in which both the mySMARTLife partner Deutsche Telekom takes part, the DIN published the DIN SPEC 91347. The specification describes current and future use cases around an integrated multifunctional humble lamp posts (imHLa) as integrated system. The imHLa has a modular design and can contain function modules from the fields of connectivity, sensor technology, actuator technology and energy systems. A prerequisite is a permanent electrical power supply as well as a connection to the telecommunications network. Several use cases describe the possible applications. The different service components should be integrated in an open standardised urban platform to enable cross domain data usage and new services. All use cases within mySMARTLife are described in the specification.

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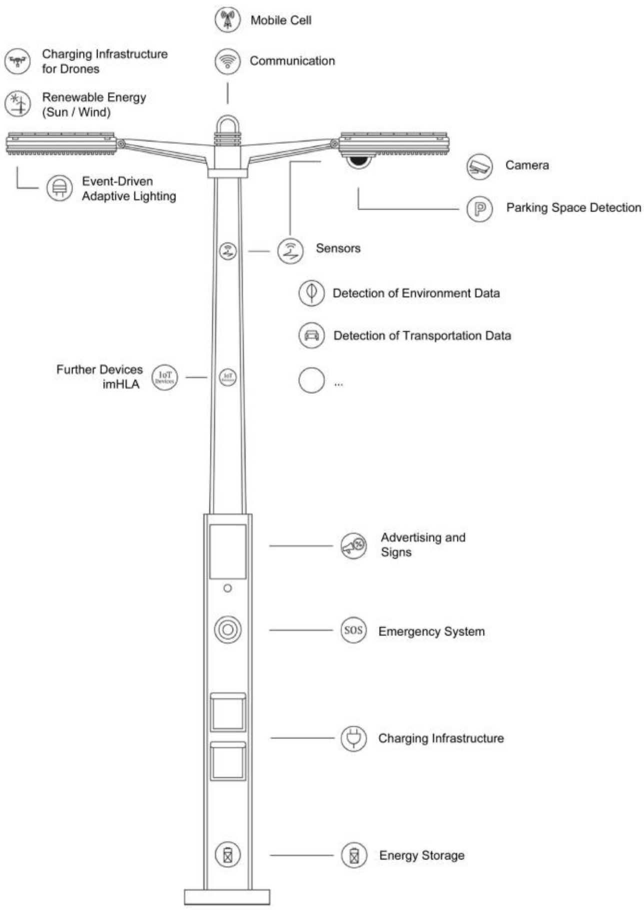

Figure 4: Schematic representation of a complex imHLA, which shows many use cases (translated from Din 2018, p.14)

4.2 LED Light

From a technical point of view, LEDs are almost ideal light sources because they are so small that they can be used to direct light to an unprecedented extent. Thus it is possible to direct the light precisely and exclusively onto a previously intended surface. Suitable applications are e.g. object lighting, lighting systems with high vibration loads (e.g. railway bridges) or systems in which the power of conventional light sources leads to over-dimensioning (e.g. handrail lighting).

LEDs are particularly suitable for use near nature reservations. The colour temperature and the spectral properties of the LEDs are proven to be insect-friendly. Light guidance concentrates on the path and produces little scattered light into the environment. The switch to LED offers the opportunity to start working on a new and complex problem in cities: light pollution.

At the same time, this has the disadvantage of eliminating the soft transition familiar from conventional luminaires. Directional radiation can also cause strong glare.

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LED technology for street lighting is currently still characterised by very frequent leaps in development. As a result, the continuous supply of spare parts is not guaranteed. Nevertheless, the technology is characterised by its good controllability and smooth dimming as well as the use of colours and white light in one luminaire.

The decision to equip the lighting system with LEDs in the project area can be made on the basis of the following points: The area at the “Schleusengraben” is a minor nature reserve (in German: “Naturnaher Bereich”) that is home to many animals. In addition, water borders the course of the path. The directional light emission with little scattered light into the environment allows the footpath and cycle path to be illuminated in a targeted manner. There is hardly any scattered light in the environment, so animals are less exposed to disturbances and light is not reflected on the surface of the water. Due to the lower system performance of the LED luminaire compared to conventional luminaires, the good controllability and the compact design, the LED is predestined to offer further services at its location.

4.3 Wi-Fi

The future of communication is called connectivity. The prerequisite for digital communication is a fast, mobile internet with high bandwidths. Due to the ubiquitous presence of street lighting, the lighting pole is particularly suitable for communicating with the population, exchanging information and making services available to the general public. The Wi-Fi-equipped lighting pole offers the user basic connectivity, which also increases the attractiveness of the location and its surroundings.

A pilot project on public WLAN hotspots was launched in 2016. Initially, access points were installed in inner-city areas of Hamburg and successfully tested. Since then, it has been possible to use internet free of charge at many tourist hotspots, in some buses and in many underground stations in the city centre. The main focus was the installation of access points at selected locations.

For the citizens, the provision of public WLAN will improve the quality of stay in public areas. The possibility of using additional services, which can be provided e.g. via the actual developed “Urban Platform”, can be used by everyone.

In the mySMARTLife project, the existing public lighting infrastructure is now combined with the possibility of additional services. In order to ensure such functions and services, appropriate transmitting and receiving units (e.g. routers, beacons) are accommodated in/on the lighting pole. Due to the measuring point operating law (see chapter 3.1) it is necessary that active components are recorded via their own electricity meter. In order to create a separate operating room, the corresponding components are not installed directly in the lighting mast, but in an adjacent switch cabinet. Due to its passivity, the antenna can be attached to the lamppost.

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4.4 Traffic Sensors (Bikes / Pedestrians / Cars)

As more and more people move to the city, the cities grow in their population although it does not grow in the area. Nevertheless, the growth in population also leads to more and more traffic. To handle this traffic within limited space, public authorities have to optimise the use of infrastructure and the traffic flow. To do so, the public authority has to improve planning processes and adapt it to the new conditions. This requires a good data basis not only for car traffic but also for cyclists and pedestrians as cities want to change the modal split to be more environmental friendly.

There are different technical solutions to detect cyclists. All of them have different strengths and weaknesses, which is the reason why in this project a combination of two technical solutions is planned to be implemented. With radar detection from the side and video detection it is expected to count cyclists with a high accuracy rate even if they are cycling in a group.

The installation the lamppost has the advantage, that both, the radar and the camera, can be mounted on the same infrastructure although they detect the cyclist from a different angle.

Initially it was planned to use infrared cameras for detecting and counting cyclists as there is a large scale project in Hamburg that uses infrared cameras mounted on traffic lights or lampposts to detect and count cars. Unfortunately first trials showed that at the moment this technology isn't able to differentiate between slow cyclists and fast runners with a high accuracy. Therefore, the camera system was chosen.

4.5 Vehicle/Bicycle Charging Station

Air pollution is a fierce problem in large cities. Therefore the City of Hamburg promotes and supports e-mobility. A key-factor for the success of e-mobility is the network density of charging stations. Charging stations provide electricity for charging electric cars along the road.

As the public lighting also should be located along the streets and is connected to the electric power system it is thinkable to use the same infrastructure for both public lighting and the charging stations. However the voltage requirements differ. A charging station that uses the same connection for the power supply as the public lighting provides a charging power of about 3,7 kW (Marx et al.,2014). Charging an electric car with such a charging power takes several hours, which is not reasonable for a charging station in the inner city as the electric car occupies rare (parking) space. Therefore a separate connection to the power supply is necessary to provide a higher charging power which implies additional costs.

However the charging power would be high enough to charge an e-bike in a reasonable amount of time. Unfortunately the expected demand for e-bike charging stations is low as a full battery charge is sufficient enough for a whole day. The E-Bike can then be charged at home over night.

4.6 Environmental Sensors

There are different indicators thinkable that could be measured by an environmental sensor mounted on the lamppost. They can be categorises in three main groups:

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- Air pollutants (e.g. CO_2, NO_x, PM_{10})
- Noise pollution
- Weather information (e.g. air pressure, temperature)

Generally each indicator is measured by a specific sensor that is mounted on the lamppost. Speaking to the responsible authorities and exchanging knowledge with other smart lighting experts indicated that the accuracy of these sensors does not meet the requirements on data accuracy at the moment (see chapter 3.3).

4.7 Adaptive Lighting

Based on a lighting management system, individual luminaires communicate with each other. Light is only provided when needed and it is controlled according to the application without impairing traffic safety. To reduce energy costs, luminaires, groups of luminaires or the entire lighting system are dimmed using modern telemanagement systems. Brightness control and light intensity are determined individually for each traffic situation. In traffic areas with strongly fluctuating use, individual road users can be detected and used to activate the highest lighting level. Pedestrians and cyclists are detected via passive infrared sensors. As soon as a road user is detected, the brightness of the surrounding 3-5 luminaires (around 100-150m) is increased. If no detection is triggered after a certain period of time, the lighting level drops back to the lower ground level within a few minutes. In the event of a communication fault, the lighting controls continue to operate in the predefined lighting profile of the lighting management system. There is no response to external events.

The area of the cycle path leads through a minor nature reserve and borders directly on residential areas. In the project area, this type of control is used to reduce night-time light pollution. In the course of the evaluation process, it will be examined whether energy savings are possible. The object of consideration is acquisition and energy supply of the additional sensors compared to the phases of low lighting.

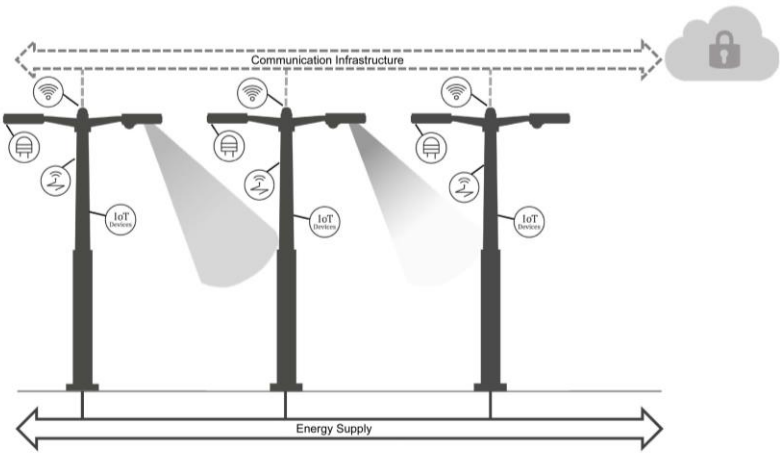

Figure 5: Use Case - Event controlled adaptive lighting (translated from DIN 2018, p.15)

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Picocell

Today's mobile radio networks consist mainly of radio cells build as macro cells on roof tops or masts that cover large areas. In the further development of the mobile communication networks smaller deployments, so called small cells or piccocells, play an important role. Used in urban areas, these additional radio cells lead to a significant increase in system capacity in the relatively small coverage area and thus to an improvement in mobile radio performance. The attractiveness of the location increases through the improvement of the mobile radio performance. Both for private houses and business districts.

The use of picocells in the project area is intended to increase the attractiveness of the newly created urban district concept. In addition, this integrated service on the lighting pole is intended to test the implementation of the integrated multifunctional humble lamppost to some extent (DIN 2018).

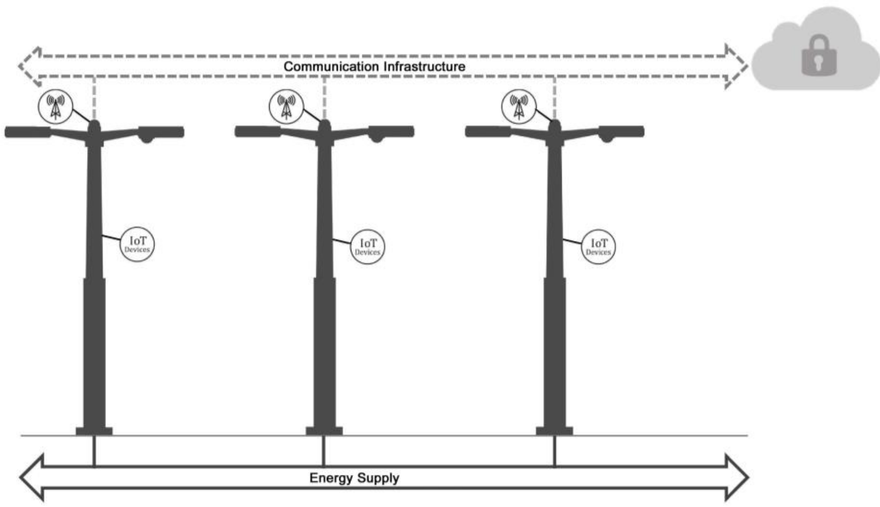

Figure 6: Use Case - picocell at lamp pole (translated from DIN 2018, p.20)

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Figure 7: Two examples to implement picocells: at the left the cell is hidden as a flower pot, at the right the cell is directly mounted at a lamp pole (source DT)

Smart maintenance

Smart maintenance in this context means intelligent maintenance of the lighting system. Sensors that record information about the status of the luminaire and its components can be used to determine remotely whether components of a lighting system have failed or require maintenance. This allows fault management to be recorded directly and centrally and forwarded for predictive maintenance.

An initial test has shown that the used components are far too short-lived. In addition, acquisition and assembly costs are not in proportion to the benefits. Hamburg will continue to monitor the development and, if necessary, develop and evaluate a new test track.

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5. Implementation Plan

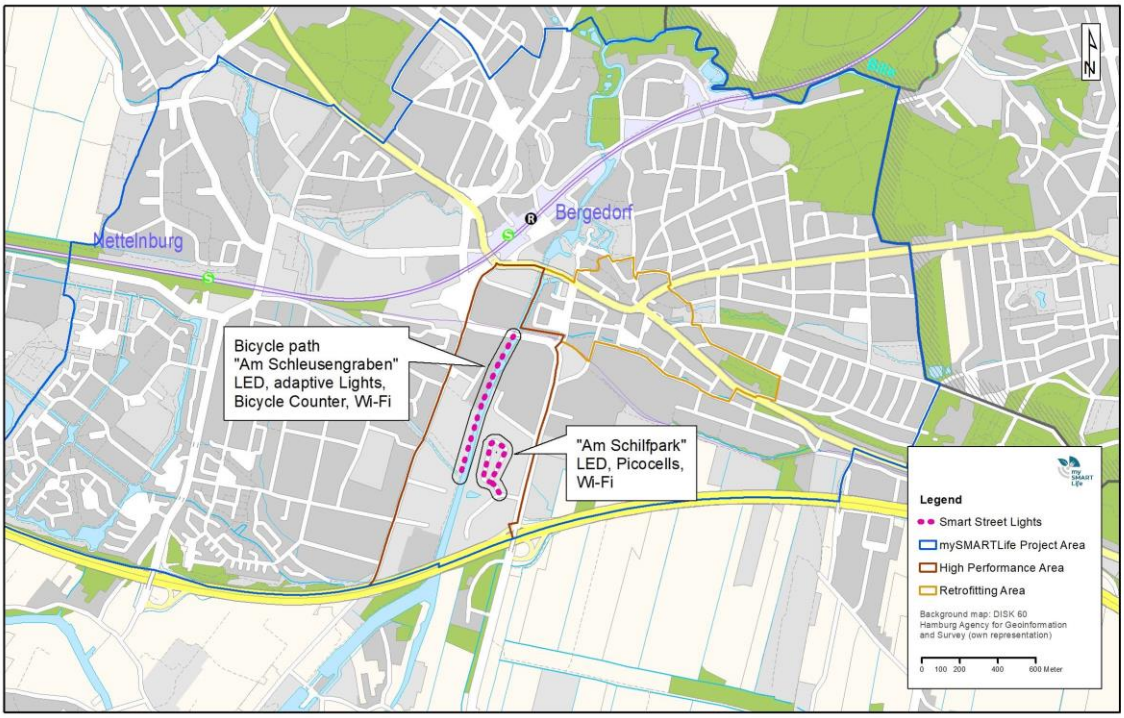

Figure 8: Overview about the smart street lights in the project area (own design)

5.1 Regional Framework

The intervention is situated in the high performance area of the project at the waterfront of the “Schleusengraben” channel, which shores are now developed from former industrial areas to new living areas, close to the inner city centre of the borough. The smart lighting is part of the new bicycle way, which will connect all new housing areas and is foreseen as an attractive connection as well as the way to school for new families and their children.

The general development of the “Schleusengraben area” is divided in six different areas, from which two “Glasbläserhöfe I+II” are already built, one is under construction (“am Schleusengraben”) and three have a delay and will start after the implementation phase of the project because of several reasons (e.g. litigations or citizen protests). This delay of the development areas and furthermore the requirement to create replacement areas for the kingfisher, which has its habitat at the shores of the channel, causes also a delay in the construction of the new bicycle connection. Since the lighting will be built at last, it therefore caused a delay in the implementation of the smart street lights. Actual it is planned to start with the construction of the bicycle lane in spring 2019 and to build the street lights in autumn 2019. The

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deployment of smart street lights with 5 Wi-Fi access points and two pico cells is planned by DTAG in Q4 2018 – Q1 2019 in the area “Am Schilfpark”.

5.2 Lighting concept at the bicycle path

Figure 9: Situation at the shores of the area “am Schleusengraben” (own source)

5.2.1 General description of the concept

The bicycle path at the Schleusengraben is intended to create a direct link from the urban development areas to the Bergedorf city centre. The path runs parallel along the water front. Due to the closely bordering buildings, the route does not offer enough space to create recreation areas along the whole way. For this reason, small viewing platforms are being designed that protrude over the edge of the river bank. Here people have the opportunity to linger.

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Figure 10: Workshop results (own source)

With its park-like green area, the area around the Schilfpark offers a place to stay that justifies the use of additional services within a residential area.

In the course of a workshop, usage scenarios were discussed and the first possible locations for additional services on light poles were selected.

5.2.2 Choice of sensors

To decide which services should be implemented at the area of the Schilfpark or along the bicycle track at the Schleusengraben, a workshop was held in spring 2017. Partners of the Borough of Bergedorf, the LSBG and T-Systems debated on possible services and application that could be implemented in one of the foreseen areas.

Based on an open brainstorming, the ideas from the project proposal and the DIN Spec were listed. After the discussion of these ideas and the placement on a plan, a preliminary concept for both areas has been worked out, which is illustrated in figure 11.

The preliminary concept for the Schilfpark integrates LED, environmental sensors, picocells, Wi-Fi and bicycle counting into the smart lighting at different lamp posts inside the area. In addition the preliminary concept for the bicycle track along the Schleusengraben also contains an adaptive lighting and smart maintenance, while the integration of picocells was not rated feasible.

As already mentioned in chapter 3 it is not seen as feasible to generate services or data without users or demands. Therefore all ideas were reconciled with relevant public agencies that have a reasonable

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demand for sensors and responsible authorities. As a result of this process of reconcilement some of these ideas where discarded for different reasons which are illustrated in the following table:

Table 3: Reasons why several sensors are not implemented

Service or Data	Responsible authority or public agency with demand for sensors	Reasons
Environmental Data	Hamburg Ministry for Environment and Energy (BUE)	- No additional data needed - Data quality does not meet the demand
Weather data	Deutscher Wetterdienst (DWD)	- No additional data needed - Data quality does not meet the demand
Smart Maintenance	Hamburg Verkehrsanlagen (HHVA)	- Life expectancy of the sensors is too low - Operating costs are too high

Further planning and reconciliation talks about the smart lighting concept moved the bicycle counter at the Schilfpark to the beginning of the bicycle path along the Schleusengraben. The final concept for the Schilfpark and the bicycle path along the Schleusengraben are illustrated in the following table:

Table 4: Sensor concepts

Development Area “am Schilfpark”	Bicycle path along the “Schleusengraben”
LED	LED
WI-FI	WI-FI
Picocell	Adaptive Lighting
	Bicycle Counter

In the following sections, the final concepts for the smart lighting in the Schilfpark and along the bicycle path of the Schleusengraben are outlined separately.

5.2.2.1 Area “am Schilfpark” (see figure 11)

The smart lighting concept for the Schilfpark contains LED, Wi-Fi and picocells. While the use of LED lighting is feasible to ensure road safety and an adequate lighting where it is needed, Wi-Fi and picocells shall raise the quality of the commercial area. By providing Wi-Fi the sojourn quality of the park and the surrounding streets shall be improved and with the help of the picocells the capacity of the mobile network

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shall be enhanced. This shall lead to a higher satisfaction of the citizens and employees in the nearby offices and create a locational advantage for these area.

To realise this effect, the placement of the Wi-Fi Hot Spots and picocells has been made with great thoroughness so that the whole area is covered by it. The position of the southern Wi-Fi hotspot a bit outside the Schilfpark will provide Wi-Fi not only at the Schilfpark, but also at the nearby bus station at the street "Curslacker Neuer Deich".

5.2.2.2 Bicycle path along the Schleusengraben (see figure 11)

The smart lighting concept along the bicycle path at the Schleusengraben contains LED, Wi-Fi, adaptive lighting and bicycle counters. As the Schleusengraben is a minor nature reserve the use of LED lighting has a lot of advantages. The light pollution is reduced and the light is directed only to the bicycle path. This ensures that the disturbance of the flora and fauna and the residents is reduced to a minimum. Furthermore, LED lighting reduces the energy consumption and is therefore environmental friendly.

It is expected that the use of adaptive lighting along the bicycle path at the Schleusengraben will optimize these effects even more. The illumination level shall reduced to a minimum if no one is using the bicycle path and shall brightened again if a biker or pedestrian is detected to provide a safe passage. It is anticipated that by this the energy consumption will be reduced, while the safety is still provided and light pollution is minimized. The adaptive lighting will be installed along the whole bicycle path. To prevent cyclists from riding into darkness, it is planned that there are always at least five lamp post enlightened in front of them.

To obtain the Schleusengraben as a recreation area, benches are built alongside the bicycle path. To raise the quality of these common areas, Wi-Fi will be provided there. Through this the recreation area is more attractive for inhabitants.

Hamburg's politics promote cycling, to reduce the share of motorized transport and resulting pollutions. Therefore a basic requirement is a good network of cycling paths. Here a solid data base about bicycle traffic is required to plan this network in the future. The bicycle path along the Schleusengraben is planned to be an important tangent from the southern areas to the inner city of Hamburg-Bergedorf. This should be verified by counting the cyclist and fostering cycling by publishing these data. The bicycles counters will be located at both ends of the new bicycle path.

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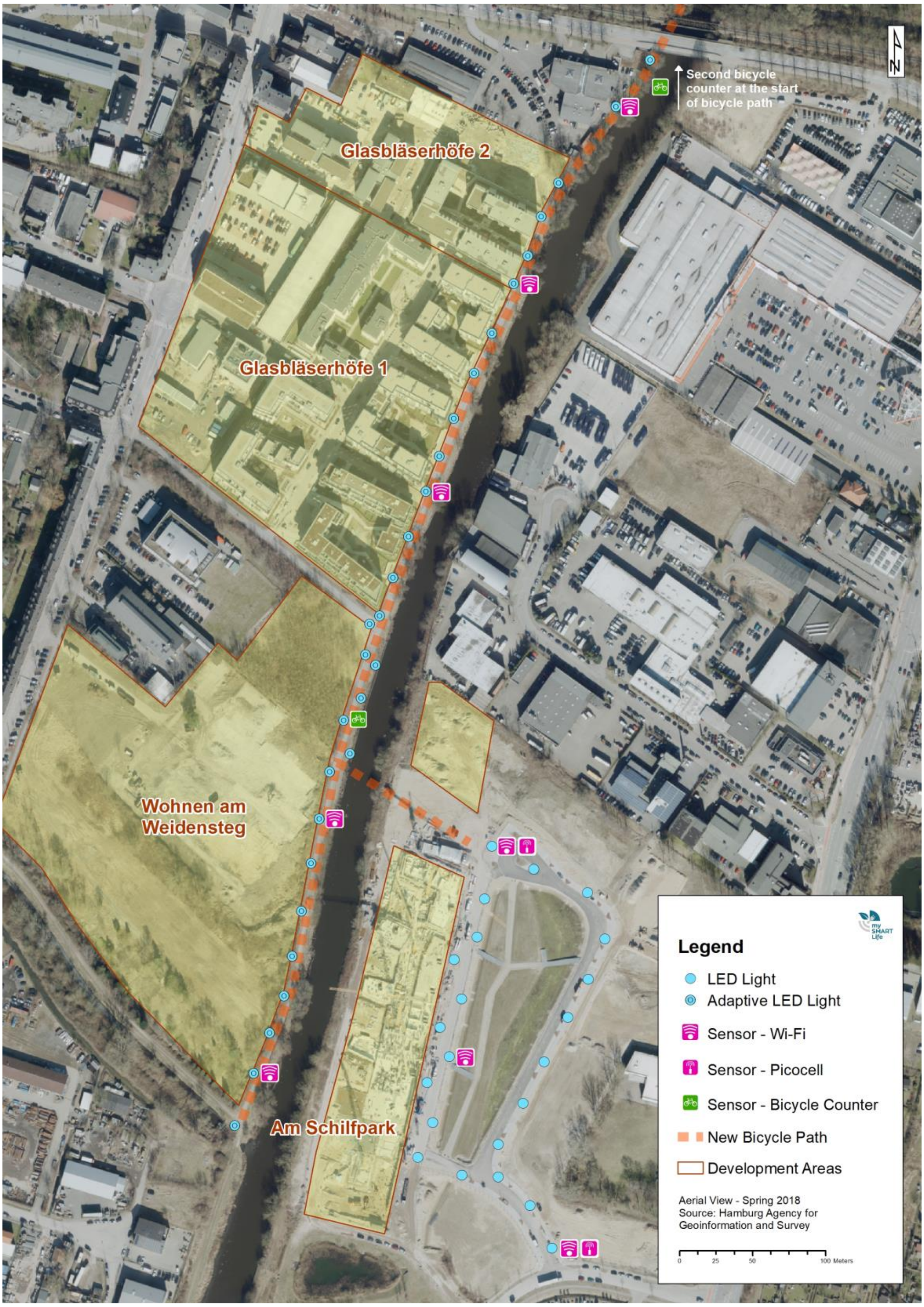

Figure 11: Implementation of Smart Streetlights in the area “am Schleusengraben” and “am Schilfpark” in detail (own design)

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6. Conclusions

The implementation of the action in the project mySMARTLife, has led to a significant increase in knowledge in the Hamburg administration about smart street lights in general. It has shown, that the technical implementation can be done without much extra effort, but the responsibility for the maintenance and operation of the different sensors causes a lot of extra coordination work for the authority which is responsible for the streetlights (in Hamburg LSBG and HHVA). So far a road construction process usually ends with the implementation of the lighting infrastructure. In the future the chosen sensors could also affect the positioning of street lights, so that an interdisciplinary cooperation between users of the sensors and the planning authority for the lighting has to start much earlier in the construction process.

Furthermore, it has shown that a wide range of sensors for a wide range of task are available on the market. But these sensors often do not match the high technical requirements that are needed by established measurement networks (e.g. the national standards to fulfil the 39. Federal Emission Control Ordinance –39. BImSchV).

It became evident, that in the field of transport measurement, the use of sensors at a lamp pole and the gathering and processing of data is most likely established, while the use of lamppost for environmental sensors, as a communication device or as future service like charging or landing station for drones, is more or less a complete new ground for the municipality. Especially sensors which start a chain of events (like an emergency button) require a comprehensive organisation of responsibilities and availabilities of authorities and couldn’t be implement in the projects lifetime.

Regarding costs and operation it has to be kept in mind, that new points of data gathering also need new data hubs in the backend. The future progress of the project will show how gathered data will be implemented in the new “Urban Platform”.

Nevertheless the City of Hamburg sees many advantages in the field of smart streetlights. Expected energy savings by the use of LED lights, the increase in mobile radio coverage by the implementation of picocells, the expansion of the public Wi-Fi network and a reduction of light pollution near to nature reserves or close to residential buildings are important improvements for the life in the city. Therefore the future development of smart lighting will be constantly reviewed and practical solution will take over to the standard set of city infrastructure of the City of Hamburg.

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7. References

DIN (2005), DIN EN 13201-1 Straßenbeleuchtung – Teil1: Auswahl der Beleuchtungsklassen, DIN Deutsches Institut für Normung e.V., Beuth Verlag GmbH, Berlin

DIN (2018), DIN SPEC 91347- Integrierter multifunktionaler Humble Lamppost (imHLa), DIN Deutsches Institut für Normung e.V., Beuth Verlag GmbH, Berlin

Marx et al.(2014), Peter Marx et al., Lade-Außenleuchte für die Elektro-Mobilität, DER ELEKTRO-FACHMANN, 61. Jahrgang 2014, Nr. 11-12/14. Available at: http://www.mx-electronic.com/pdf/Publikation-Lade-Aussenleuchten-im-E-Fachmann-2014.pdf [27.11.2018]

Verg (1982), Erik Verg, Licht für Hamburg, 600 Jahre öffentliche Beleuchtung - 100 Jahre elektrische Straßenbeleuchtung in Hamburg, Hamburg: Hamburg Elektrizitätswerke, 1. Auflage, 1982

Referenced laws and regulations:

39. BImSchV: Neununddreißigste Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verordnung über Luftqualitätsstandards und Emissionshöchstmengen - 39. BImSchV). Available at: https://www.gesetze-im-internet.de/bimschv_39/ [22.11.2018]

Gesetz zur Digitalisierung der Energiewende. Available at: https://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&start=//*[@attr_id=%27bgbl116s2034.pdf%27]#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl116s2034.pdf%27%5D__1543398813408 [28.11.2018]

Hamburger Gesetz über Grün- und Erholungsanlagen. Available at: http://www.landesrecht-hamburg.de/jportal/portal/page/bshaprod.psml?showdoccase=1&st=lr&doc.id=jlr-GrAnlGHArahmen&doc.part=X&doc.origin=bs [27.11.2018]

HWG, Hamburgisches Wegegesetz in der Fassung vom 22 Januar 1974. Available at: http://www.landesrecht-hamburg.de/jportal/portal/page/bshaprod.psml?showdoccase=1&st=lr&doc.id=jlr-WegeGHArahmen [27.11.2018]

MsbG, Gesetz über den Messstellenbetrieb und die Datenkommunikation in intelligenten Energienetzen. Available at: https://www.gesetze-im-internet.de/messbg/ [22.11.2018]

ReStra, Hamburger Regelwerke für Planung und Entwurf von Stadtstraßen. Available at: https://www.hamburg.de/contentblob/9225042/855ddf23faf5d39b434eca3fd25ccfe6/data/restra.pdf [27.11.2018]

R-FGÜ, Richtlinien für die Anlage und Ausstattung von Fußgängerüberwegen, Verkehrsblatt-Verlag, 2001. Available at: http://www.verkehrsblatt.de/docs/archivanzeige.php [27.11.2018]

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