Integrated Infrastructure

Deliverable n°4.4.2

Version 1.0

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Glossary

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Executive summary

The integrated infrastructure in Freiham Neuaubing Westkreuz in Munich consists of an installation of 60 newly developed “intelligent lampposts”. The City of Munich department “Baureferat” (Building Division) developed intelligent new lampposts as a blueprint in cooperation with the Munich IT-Department “RIT”, internal and external experts and Munich Service Utilities SWM. The already existing standard lampposts were used as construction basis and adopted according to the requirements to be applied in the project area (“real lab”). The Baureferat is responsible to assure the general functioning of all lampposts and safety for traffic in the city. The external design of new intelligent lampposts thus is comparable to existing ones. Only a specialist is able to distinguish between an existing old “standard lamppost“ and a new “intelligent lamppost“.

Besides basic technical infrastructure for street lighting, intelligent lampposts further contain additional installation space for small electric devices, offer an additional electric power supply for sensors which is independent from the powerline for light and data connectivity like fibre optic cables or wifi. The communication infrastructure provides the standard Munich free public wifi called-“M-WLAN” and serves for communication with the IoT devices installed at the lampposts.

This approach allows maintaining the “lighting part” of the intelligent lampposts with existing tools and knowledge. In parallel, it allows to install and to run innovative sensor and actuator solutions in and on the new lampposts, and enables the transmission of measured data to the Smart Data Platform or to other data storage mediums.

New lampposts were installed along four roads within the project area, that are Bodenseestr., Limesstr., Wiesentfelser Str. and Ellis-Kaut-Weg also named Grünfinger in this report.
In all mentioned roads the 10m-model (lamppost with a height of 10 meters) of the intelligent lamppost was applied (“LM10_SC”). Only in the Ellis-Kaut-Weg, which is a footpath in a park environment, the 3m model (“LM3_SC”) of the new designed intelligent lamppost was installed.

This deliverable’s goal is not to investigate the smart lighting aspects of lampposts. The lampposts are mostly used as an (IT-) infrastructure for sensors and actuators. The main goal and focus of the lamppost development and installation within the SMARTER TOGETHER project is to provide a “Real Lab” environment, where innovative Smart City solutions comprising sensors and actuators can be installed and tested in the field. Furthermore, the goal of the “Real Lab” was to develop an intelligent lamppost that meets all requirements of the city. These are a maximum usability of existing and future data transmission options for sensor and actuator solutions, a recognizable lamppost design, following standards in construction, cost efficiency, an easy-to install deployment and a maximum reuse of existing tools and knowhow. Before expanding intelligent lamppost or sensor installations all over a city, all aspects that might influence the
underlying benefit and business cases need to be verified in detail. The Real Lab, built for the Munich SMARTER TOGETHER integrated infrastructure project, offers a perfect environment for the City to test and benchmark innovative sensor solutions, before they are rolled out in other city areas or could be replicated by other cities. Trusting marketing sales forecasts and manufacturers does not pinpoint the actually required values for the City. Only experiences in real environments, including installation, maintenance and evaluation of the results during longer periods of time, can filter the innovation a Smart City requires from unnecessary but expensive marketing bubbles.

As this lamppost infrastructure is build and run by the city departments, there is a full control on usage, installed solution and services and guarantee of high quality standards defined by the city, regulations or law.

In two innovation tenders in 2017 and 2018 (so called “Open Call”), the City of Munich selected sensor based solutions for the lampposts. The first Open Call at the end of 2017 focussed on sensor solutions dedicated to weather conditions and air pollution measurement. Before submitting the open call tenders, all stakeholders’ requirements concerning the potential sensor solutions were collected in different formats. Examples for the different formats are Co-Creation seminars with citizens and dedicated workshops with involved city departments and project partners.

The second Open Call in summer 2018 focussed on solutions for traffic counting and on board parking management.

In both tenders, the intelligent lamppost played a central role. All solutions offered by start-ups, established companies or universities had to comply with system requirements of intelligent lampposts of the City of Munich.

The installed IoT devices will deliver data to the smart data platform following the regulations defined in the Data Gatekeeper concept. These data will be available for real-time processing, data analysis or in the long term for prediction and simulation of city scenarios. For visualisation, the data is presented in webinterfaces (browser) or mobile services integrated in the Munich Smart City App. In addition, the data is used for monitoring purposes or KPIs if required.
1. Introduction

1.1 Purpose of the document

This document aims at providing a detailed documentation of the integrated infrastructure deployed in Freiham/ Neuaubing-Westkreuz, the SMARTER TOGETHER project area in Munich, which consists of intelligent lampposts.

It shall give a short and comprehensive description of both technical aspects of newly designed lampposts as well as of installed sensor solutions of the two first innovation tenders (Open Calls).

After reading this documentation, it should be clear how the lampposts have been designed and installed in terms of components and functionalities, framing conditions for construction and operation, why certain technical decisions have been agreed on together with the project stakeholders, and what benefit the lampposts provide to SMARTER TOGETHER and the City of Munich.

In the course of this, the document covers two major topics: the lamppost design including its technical components, as well as the data connection possibilities offered by the intelligent lampposts.

1.2 Structure of the document

Chapter 1 describes the purpose and structure of the document.

Chapter 2 serves as the deliverable of the integrated infrastructure. It gives an overview of the technical design and functional system elements of the lampposts.

Chapter 3 describes a practical example of a pilot study within the Munich integrated infrastructure. An overview of the sensor installations is provided.

Chapter 4 briefly summarises the deliverable and discusses first experiences and possible next steps.
2. Requirements and specifications

In this chapter, evolutionary steps are outlined, explaining how the intelligent lamppost evolved from the existing lamppost, especially focusing on the project requirements towards the integrated infrastructure, which led to adaptations of the existing product for the context of SMARTER TOGETHER.

The technical specifications of the intelligent lamppost will further be described in this chapter, as well as first installations of sensors.

2.1 SMARTER TOGETHER project requirements towards an “intelligent lamppost”

Before establishing the integrated infrastructure project based on a number of “intelligent lampposts”, it was first required to define and design such an intelligent lamppost.

In various discussions with all specialists of the city, six main requirement pillars where identified. At a minimum, a new intelligent lamppost had to comply with specified aspects:

(1) A lamppost has a lifetime of at least 20 to 30 years. The main task of a lamppost is to serve as infrastructure for a reliable source of light in public space. Any newly designed lamppost therefore must assure that the installed existing lighting technologies, but also current and future technologies e.g. LED or adaptive lighting can easily be installed.

(2) A large city like Munich has installed thousands of lampposts - in fact about 80,000. All of them require regular maintenance and at times a replacement of electric or mechanic elements. The staff being responsible for this work needs special training and tools to fulfill this work with a minimum amount of time and effort. The minimization of costs in this environment is an important task for the city. Any newly designed “intelligent lamppost” therefore should offer the same structures, knowledge requirements, tools and technical elements that already exist, at least for the lighting part of the lamppost.

(3) A city often has policies for the appearance of elements in public space. A common design of those elements can strongly influence how an urban district or the whole town is perceived by inhabitants. Also when using same design elements or specifications all over a city, investment costs can be kept to a minimum, especially with elements like lampposts, that scale to large numbers. A new intelligent lamppost design therefore needs to follow strictly the existing city

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1 EU Initiative https://eu-smartcities.eu/initiatives/78/description
policy. Any new design of a lamppost often increases costs and changes the “look and feel” of a district. In some cases the “new look” can be used on purpose to underline a new character of a district or to highlight special technical innovations. A mix of old and new elements might also disturb the existing sense of space of an area. Therefore, it is important to discuss the possible impact of a new design, even if it is “only a lamppost”.

(4) A lamppost has to fulfill very strict static specifications. The safety to traffic does not only influence the choice of the lighting source, but also the mechanical stability of the lamppost under all possible weather conditions. When adding new elements to a lamppost, like sensors or actuators, it affects its statics. A large 15 kg sensor installed on a 10m height can heavily destabilize the statics of a standard lamppost, especially when additionally covered with snow or during storms. The necessity of having three lamppost access openings and working areas instead of one changes the statics and requires an adapted design of the lamppost. A new intelligent lamppost design has to take into account all of these factors.

(5) On top of the reliable lighting, an intelligent lamppost offers many other new technical possibilities. Sensor electricity needs to be available 24/7, whereas lighting electricity is cut-off during daytime. Sensors need wired or wireless data access, whereas lighting infrastructures are often only connected to standardized power supply. Sensor activities must not influence the normal lighting activities at any time. Therefore, when designing an intelligent lamppost, it must be considered that both areas, lighting and smart city infrastructure, should be physically separated and totally independent in operations. Depending on legal requirements in other countries and/or city policies, e.g. in the context of electricity billing of lamppost usage, the final design might slightly vary.

(6) In a Smart City, there are various areas where intelligent lampposts including innovative sensors will be required over time. In a huge city, potentially hundreds or thousands of new lamppost installations can be required. Thus, cost efficiency is of great importance. A newly designed intelligent lamppost that can be built with existing manufacturing tools is potentially much cheaper than a completely new approach. The more standardized an intelligent lamppost can be manufactured, the more lamppost providers are able to participate in tenders, and the lower the costs for a city.
2.2 Used technologies for main components

In total, the project area required the design of two different lampposts. One design consists of a 10m lamppost (“LM10_SC”). This height is mainly used in Munich’s main roads. The other lamppost design of 3m height (“LM3_SC”) that was designed to comply with architectural requirements for the new developed park in Freiham.

All static requirements and technical designs were processed and developed by the Baureferat of the City of Munich and approved by external experts.

The LM10_SC intelligent lamppost has a comparable technical and skeletal structure as the existing old lamppost, although two main differences can be observed:

1. First, the increased diameter of the basic body. It is slightly larger compared to the old lamppost. The main reason is that additional smart city-related electric components need to be manually integrated into the lamppost. As three access

![Figure 2: Detail picture of the three working spaces within the intelligent lamppost LM10_SC](image)
doors were required, the lamppost statics needed a revision. The additional components can be e.g. separate power supplies that feed all sensor and data connection related equipment, data hubs to connect sensors and actuators or any equipment required to assure a secure data handling and connectivity. For this reason the intelligent lamppost offers three separate workspaces (see Figure 2). For security reasons, every access lock is closed with a special key.

(2) The intelligent lamppost LM10_SC offers three separate doors dedicated to the workspaces “Lighting”, “Power Supply for Sensors” and “Communication Devices for Sensor Data”. The main reason for the separation is the required autonomy between the two “data-workspaces” and the “lighting” aspect of the lamppost.

As illustrated in Figure 2 above, the lowest workspace is exclusively dedicated to the lighting infrastructure, consisting mainly of the separate power supply and possible fuses. The mid door gives access to the power supply for the sensor equipment. The door above allows access to the workspace where devices that are required for the communication or pre-handling of data arriving from the sensors can be installed.

If needed, glass fiber cable and converters can be installed into the data workspaces of the intelligent lamppost. The available bandwidth is usable to operate WLAN hotspots at the lamppost, or to assure a wired Ethernet connection to the sensor equipment.

Sensors and actuators are in most cases attached at the outside of the lamppost body. Depending on the nature of the collected information (weather, air quality, traffic flow, etc.) the sensors can be installed between 3m and 10m height. The Baureferat developed additional fixtures to enable a specified sensor mounting and to avoid a potentially non-structured and discretionary sensor attachment. On top of this, a fixture can avoid vandalism damage to a certain degree.

Concerning the nature of the installed data equipment, the main restriction is the available workspace within the intelligent lampposts. All equipment can be fixed at a top hat rail that is included in the basic lamppost. Although the intelligent lamppost workspaces are water protected, it is recommended to protect the data equipment against condensate (high IP grade for protection).

Other unknown factors for the operational reliability of the data equipment (which often consists of mini-computers) in the intelligent lamppost could be e.g. the internal microclimate.

It is expected that the internal lamppost humidity and temperature vary considerably during the year. Whether or not these changing environmental conditions show a visible impact on the sensor solutions is one of the aspects of concern to be observed over time.
The **LM3_SC intelligent lamppost** has a comparable technical design. However, one main difference compared to the **LM10_LC** is the even more restricted workspace within the lamppost body.

For that reason, the lamppost designers decided to remove some of the workspace into an external bottom pontoon, placed underfloor nearby the lamppost. Mainly the access and conversion of fiber cable and the power supply equipment are installed in this waterproof space (see Figure 4).
2.3 Installation of the lampposts

The installation of intelligent lampposts was carried out in four different places within the Munich project area. All lampposts were installed between summer and fall 2017.

Figure 5 below indicates the Integrated Infrastructure area (“Real Lab”) with four different streets with lampposts installed:

- 17 intelligent lampposts LM10_SC are installed in Limesstr.
- 24 intelligent lampposts LM10_SC are installed in Bodenseestr.
- 3 intelligent lampposts LM10_SC are installed in Wiesentfelserstr.
- 16 intelligent lampposts LM3_SC are installed in Ellis-Kaut Weg
Figure 5: Site map of SMARTER TOGETHER project area Munich: installation sites of integrated infrastructure / intelligent lampposts in Munich real lab.

Figure 6 below illustrates the installation process for LM10_LC at Bodenseestr. The orange cable is reserved for the electric power of the lighting. The black cable is set for the electric power of sensors.
Figure 6: Installation of intelligent lampposts LM10_SC at Bodenseestr. in spring 2017
3. Demonstrator

3.1 Intelligent lampposts installed and equipped with sensor solutions

After the lamppost installation phase was completed, a newly designed Munich tender process took place. This process was named “Open Call”. It included an overview of the technical design and functional system elements of lampposts. It has been designed as a specific tender process not to identify established products but rather to identify innovative solutions. The new Open Call format has been developed in close cooperation with the responsible “city contracting department”, and considered relevant elements of the existing procurement laws. In contrast to a more traditional tender, the open call asks interested companies, start-ups or universities not to offer dedicated sensors, but to offer innovative end-to-end solutions for predefined topics like e.g. air pollution (open call 1) and traffic counting (open call 2). The call has outlined technical and organisational requirements, assessment criteria, the need for an integrated solution within the intelligent lampposts and the nature of the “Real Lab” experimental nature of the project.

To commence with actual activities in the Munich Integrated Infrastructure area, the local project team has decided to publish the first open call in fall 2017. The topic was defined as an innovative sensor solution around environmental and air pollution measurement. A senior management jury team of the city selected two winners: Hawa Dawa, a Munich-based Start-Up specialized in environmental sensor solutions that measure PM 2.5, PM 10 and NO₂, and Vaisala, an established Finnish company dealing with sensor solutions that also measure PM 2.5, PM10, NO₂. In addition to HawaDawa, Vaisala is able to offer sensors that measure wind, precipitation and other meteorological measurement data.

In close cooperation between the selected companies and the Baureferat, the sensor solutions were successfully installed and fine-tuned during spring and summer 2018. They have been in operation since then, transferring their measurement data into the SMARTER TOGETHER Smart Data Platform. 3 of 4 Hawa Dawa Sensors (two in Bodenseestr., one in Limesstr.) transfer their measured data via secured WLAN.

The Wi-Fi infrastructure is provided by SWM (Munich public services). The service “M-WLAN” is a free of charge wireless communication service open to all people in Munich at dedicated locations in the city center or touristic areas. The password-secured mode of the M-WLAN service is used to connect the sensors and actors of the SMARTER TOGETHER project to the Smart Data Platform and to the solution providers that run the sensors. The M-WLAN hot spots are installed at several intelligent lampposts (five in Limesstr., two in Wiesentfelserrstr., five in Bodenseestrt., two in Ellis-Kaut Str.) in order to assure a Wi-Fi coverage of the respective areas and use the integrated fiber cable /
Ethernet infrastructure to connect to the Internet. In parallel to the M-WLAN option, one Hawa Dawa Sensor (Ellis-Kaut Weg) transfers the measured data through the available LoRa network, which is provided by the SWM too. The locations of the sensors can be seen in Figure 8. The LoRa network is not part of the SMARTER TOGETHER integrated infrastructure, but the project team decided to test this technical connectivity, because it was available. The two Vaisala sensors in Wiesentfelsstr. transmit their measured data via a 3G network.

Within the “Analysis Dashboard” of the Smart Data Platform, all data is collected, analyzed and displayed. Only dedicated city experts and project partners have access to this dashboard. Due to the sensible and often complex data analysis, it is not available for a broader public. At the time of writing, it is still too early to conclude on reasonable results of the analysis. This will be done during and after the monitoring phase of the SMARTER TOGETHER project.

Small and cost optimized sensors (like the HawaDawa sensor) often need an initial adjustment. This “calibration” ensures a best possible measurement data quality. For this procedure, it is important to dispose of a reference sensor with proven measurement quality installed in a comparable location. To compare and calibrate the SMARTER TOGETHER environment sensors, an additional Hawa Dawa Sensor has been installed outside the project area near the city center (at Stachus / Karlsplatz), a location that offers enough additional installation space for the HawaDawa sensors, located nearby.
the reference sensors. This has been performed in close cooperation with the “Landesamt für Umwelt” (LfU), the official Bavarian institute that operates five reference stations for air quality measurement in Munich (Allach, Johanneskirchen, Landshuter Allee, Lothstr. Stachus).

- The following data is measured in the HawaDawa sensors, transmitted to the Munich SmartCity App and into the smart data platform: NO₂, O₃, PM₂.₅, PM₁₀, temperature, air humidity, air pressure.

- The following data is measured in the Vaisala sensors, transmitted to the Munich SmartCity App and into the smart data platform: NO₂, O₃, SO₂, CO, O₃, PM₂.₅, PM₁₀, air temperature, wind, air pressure, and precipitation.

The second tender took place in summer 2018 and focused on traffic counting and parking management solutions. The city of Munich decided to select up to two winners per item (traffic counting and parking detection) to have a good base for comparison of the offered basic company solutions. In this Open Call, the jury selected three winning companies in late summer 2018. The installation is scheduled for winter 2018.
The winners are Eluminocity for traffic counting and parking management. Eluminocity is a Smart City Solutions Start-up located in Munich. The second winner for traffic counting is ParkHere in a consortium with Swarco. Swarco is an Austrian traffic solution provider, ParkHere is a Munich based Start-up for Smart City solutions. A second winner for parking management is a consortium between Axians and Cleverciti. Axians is a multinational project integrator, Cleverciti is a Smart City Solutions Start-up located in Munich.

The discussions to determine the process for the installations of the sensors will start in fall 2018 together with the winners.

### 3.2 Intelligent lampposts - technical details

The following illustrations (Figure 9-13) are extracts taken from the Open Call tender documents. They show examples of the original technical base description of the LM10_SC and LM3_LC lampposts as well as detailed maps of the lamppost positioning, designed on purpose for lampposts installed in the integrated infrastructure project within SMARTER TOGETHER Munich.

![Figure 9: Structural overview of an intelligent lamppost for the integrated infrastructure / real lab in Munich](image-url)
Figure 10: Overview of the wiring diagram of an intelligent lamppost LM10_LC (example Bodenseestr.)
Figure 11: Dimensioning of the different lamppost doors of an intelligent lamppost

Figure 12: Detailed location plan of the Bodenseestr. incl. the positions of the intelligent lampposts LM10_SC
Figure 13: Detailed plan of the LM3_SC intelligent lamppost
4. Conclusion and outlook on next implementation steps

The preliminary studies, the decision-making of which technical approach to perform and to build an integrated infrastructure in Munich, the final design and the installation of lampposts were the result of large workshops with all Munich SMARTER TOGETHER team members and participating industrial experts. Baureferat has coordinated the process details of design, final verifiable statics, the electrical and mechanical project planning as well as the roll out and actual installation of intelligent lampposts and selected sensors.

Although a lamppost does not seem to be a complex entity for outsiders, the complexity and the innovation potential of an intelligent lamppost are often underestimated. Detailed planning is needed for the provisioning and installation of the required additional and local electric power supply and Internet cabling. It is a challenge to install additional glass fiber cables and an additional power supply for the sensor infrastructure, which results in complex, expensive and difficult construction works in existing public spaces.

A complete exchange of all existing “analog” lampposts in the favor of intelligent lampposts is not required in all city roads. Often the installation of only a few intelligent lampposts, well positioned in dedicated roads, including the required actuators and sensors already offer a good database to analyze the complete road or even a city area (e.g. parking management, traffic analysis or local air quality status). From a business case perspective, it is neither realistic nor viable to replace every existing lamppost with an intelligent one.

On the other hand, the relevance of an intelligent lamppost in an urban environment is obvious, when positioned in defined areas, such as crossroads. The fact that an intelligent lamppost offers additional 24/7 power supply (in parallel to the lighting electricity) and a reasonable bandwidth for data transmission, makes an intelligent lamppost a very attractive Point of Interest (POI) in a city. Several potential replication requests are discussed in the City of Munich already.

The integrated infrastructure and with it the Real Lab environment offer a very attractive possibility, not only to test new approaches and technologies for the city, but also to show the available technical options and with this, discuss new projects and convince potential future city operators to reasonably invest in intelligent lampposts and innovative sensor solutions.

Next steps for the continuous usage of the integrated infrastructure of SMARTER TOGETHER in Munich will be the installation of additional sensor solutions deriving from the Open Call 2 (Traffic Counting & Parking Management). The monitoring of the analyzed data and the discussion with the dedicated city specialists will then potentially lead to much better and quicker decision-making processes, when investing in future sensor
solutions for upcoming projects in Munich (like e.g. a common and integrated Traffic Data & Management Platform for Munich).

As replication of findings and deliverables in SMARTER TOGETHER - like the “intelligent lamppost” and corresponding infrastructure concept - are very important, a webinar, articles and talks on various conferences have been given to share experiences and ideas.
References

Webinar “Intelligent Lampposts in Munich”:

https://www.youtube.com/watch?v=DpFlnPshHvE

Link to the open call 1 for sensor installations referring to the intelligent lamppost (incl. technical documentation). In German language only: