International Smart City plans, experiences, success factors

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With UrbanPulse the global company [ui!] – the urban institute® has developed a real-time sensor data platform, which is aligned with the vision of open urban platforms, as defined by the European Innovation Partnership on Smart Cities and Communities (EIP SCC). Therefore, UrbanPulse is an information platform for urban data. It has at its disposal a highly scalable architecture for data processing and analysis for the simple integration of sensors and other urban management systems. Best case practices from the cities of Darmstadt and Bad Hersfeld in Germany showcase the added value for the citizens and the public administration.

1. Introduction

Urban data is the basis for the communication in a smart city. The complexity of a city and its communication streams lead to a multitude of different data, which exist in every city already today. In the next years, the digitalisation of economy and society will significantly enhance the amount of data in a city.

Urban data, which is already used by cities, for example, as traffic data from the traffic control centres, signal switching times at cross roads, energy consumption of municipal utility companies, radar sensor data, construction site information, registered events, measurements from air or emission data, just to name a few.

This data "is the commodity of the 21st century" as German chancellor Angela Merkel said at an event in Berlin on November 2nd 2015. For cities, this means that they are sitting on a figurative oil field and have access to a valuable resource. The data a city and its citizens produce is a raw material. But only processing turns crude oil to gasoline and creates added value for the consumers. In parallel, cities need to achieve integrating and structuring their data in a way that it becomes usable for citizens, companies and administrations.

In other words: Big data needs to be transformed into smart data.

[ui!] the urban institute® is dedicated to developing evidence-based insights that improve people's lives and strengthen communities. From fleet services to carbon dioxide reduction in cities.

The company effectively identifies gaps in a city's existing data ecosystem, and merges existing with new data to create a platform that affords relevant smart services. By collaborating with lawmakers, community leaders, corporations, and grassroots change-makers, the company diagnoses problems and designs roadmaps, creating core technologies that serve a city well. From fleet services to carbon dioxide reduction in cities, [ui!] interconnects different systems of a city to deliver the best smart results.

Section 2 provides an overview of the European Framework for the advancement of smart cities and communities. Enabling cities to use their data resources, is the main objective of value added services based on open data. Two cities which have also joined some of the standardization projects and are deploying smart data solutions in the cities are Darmstadt and Bad Hersfeld. Their experiences are depicted in Section 3. The basis for urban data is the domain spanning architecture of the platform (Section 4). Here, the heterogeneous sources of data in a city can be integrated in the platform (Section 5). To aid the implementation of such solutions and services on top of them, which create added value to the citizens, standards have been developed for the last years (Section 6).

2. EU Initiative: open urban platforms become the digital tools for smart cities

The company was founded to support the objective of the European Innovation Partnership on Smart Cities and Communities (EIP SCC) [1]. In his role as the Chairman of the SMART CITY Forum [2], a think tank and network of cities and industry, [ui!]'s CEO Lutz Heuser engaged with EU Commissioner Guenther Oettinger on the Smart Cities and Communities Initiative to establish a European Innovation Partnership (EIP) in 2012.

The EIP SCC is an initiative supported by the European Commission. Aiming at overcoming market fragmentation, the EIP-SCC brings together cities, industry, financers, and citizens to improve urban life through more sustainable integrated solutions. Its Market Place has already 5,300 members from 31 countries.

The structure of the EIP SCC entails six action clusters:

- Citizen Focus
- Integrated Planning, Policy & Regulation
- Business Models, Finance and Procurement
- Integrated Infrastructures and Processes
- Sustainable Districts and Built Environment
- Sustainable Urban Mobility

The author of this paper is the chairman of the action cluster "Sustainable Urban Mobility".

A significant intermediate result in the area of "Integrated Infrastructures and Open Data" is the demand for open urban data platforms as an important precondition for the fast implementation of smart city solutions, which are open and accessible for everyone in the city.

The first step in this direction was the "Urban Platforms Initiative", in which three groups work together: the demand side (primarily cities), the supply side and the standardisation bodies. With the memorandum of understanding "Open Urban Platforms for Smart Cities and Regions" [3], the initiative aims at promoting open urban data platforms. Together they want to define the requirements for open interfaces for open urban platforms. The early adopter also formed the core group of the standard development (see Section 6). The data platform from [ui!] the urban institute®, called UrbanPulse, is one of the first urban data platforms which has implemented those requirements in its architecture. It is described further in the following section.

3. Urban Data for new services in cities

The open urban data platform UrbanPulse enables [ui!] and other stakeholders to build value added services based on data which is enhanced as urban data. Added value arises by bringing this information together on one platform, the data is made available for various applications on top on it. These value added services could be provided either for the management of a city itself or directly as a service to citizens.

3.1 Use Case: Digital City Darmstadt

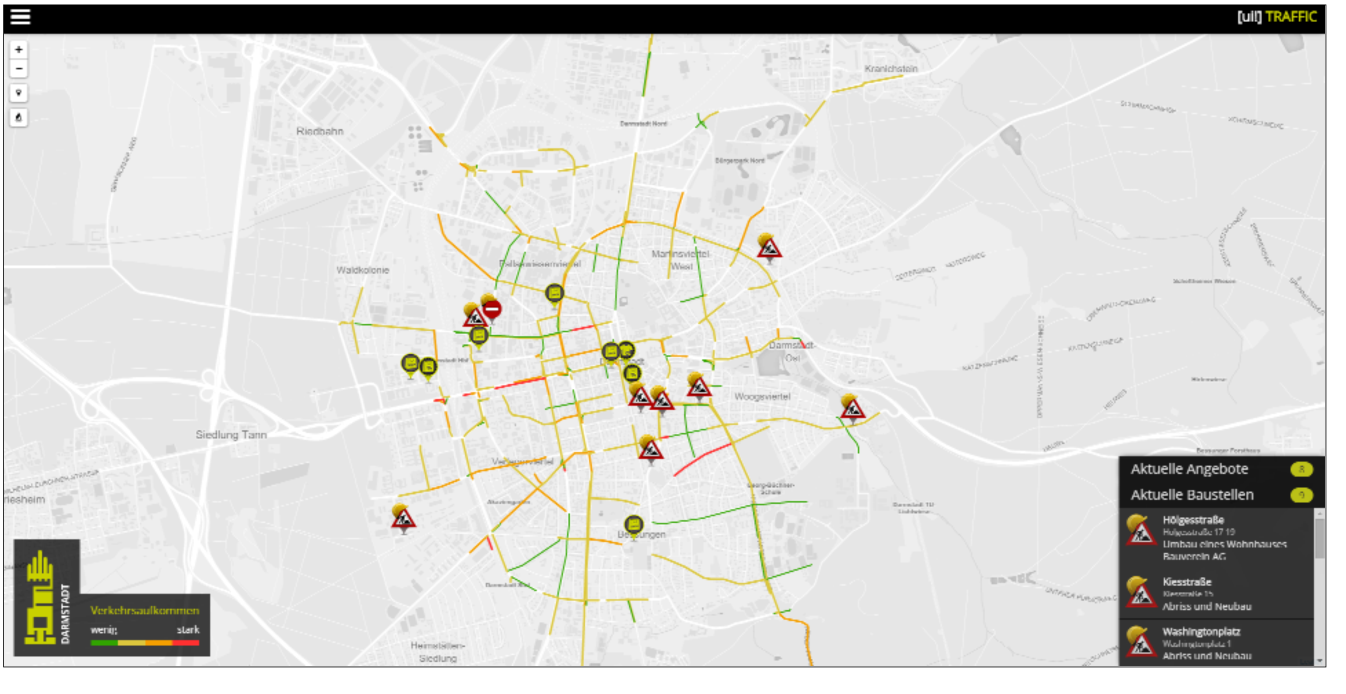
The first value added service that was created makes use of traffic patterns, big data analysis and commuter profiles including departure times and routing information to compute slot based travel recommendations. These recommendations are provided by an application for commuters and citizens of Darmstadt and include a proposition for their departure time. Thus, they can minimize their travel time and fuel consumption, as well as lower the peak traffic within the city.

The city of Darmstadt is situated in the middle of Germany, close to Frankfurt Main. With its 150,000 inhabitants it faces many challenges typical for cities of this size in Germany and other European countries. The city has recently in June 2017 won the German national competition "Digital City" organised by the German Federal Association for Information Technology "bitkom" and the German Association of Towns and Municipalities [4]. From 2018 on, sectors like traffic and energy will be provided with latest digital technology. Public administration will offer innovative online applications and commerce intelligent delivery services.

By networking some of the existing data in Darmstadt on the platform, synergies arises. Since the future of cities and regions is shaped by new ICT technologies on the way to Smart Cities [5], those synergies will gain more and more importance.

The testing of the traffic solution started in spring of 2013. Today the solution is alive. Citizens can access the traffic information via an app that visualises the real-time traffic situation on a map [6]. The data is collected from

Figure 1. Real-time traffic information for citizens



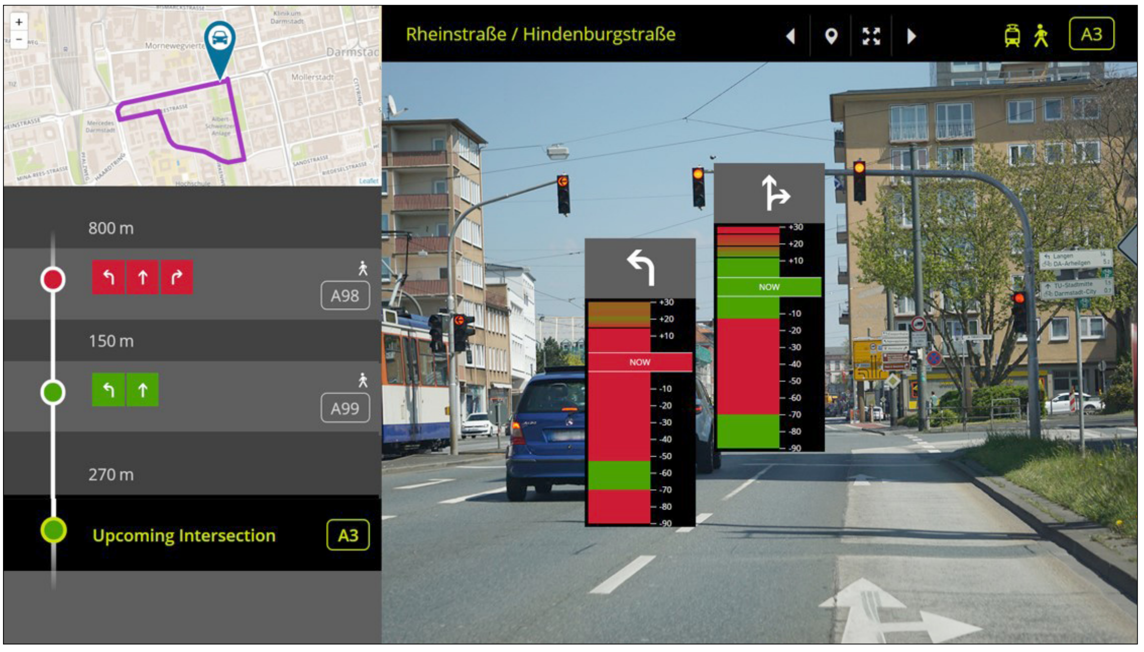


Figure 2. Traffic light assist – Web App

the existing urban traffic light signals. This has the advantage that the data is not personalized. The scalable platform architecture allows to handle this multitude of data in real time. The basis for this service is the Urban Pulse, [ui!]'s IoT data platform. It acts as an interface to Darmstadt's main traffic management computer and processes big amounts of data in very short intervals. The processed data is then enhanced and made available as open data. City employees from the civil engineering authority also have the ability to import information about the expansion of road junctions in the system, thereby keeping the system up to date. On the other hand, this information is also used by the road authority to make geo-referencing of sensors within an administration tool.

With this open data platform for traffic data, the city of Darmstadt is a pioneer for the digitalisation in the mobility sector. The provision of traffic data for citizens as well as for companies, e.g. from the automotive branch, is the foundation for new digital services for increased traffic flow and creates unique conditions for driving with driver assistance systems. This fosters the development of autonomous driving and other innovative changes in society.

One of the main characteristic of the app is the high upgrade grade, which is particularly important for the city centre. With the information from the app, each user can decide which option is best at this particular point in time, see *Figure 1*.

The second service in Darmstadt is directed towards the automobile industry in the context of current developments for connected cars. Generally, the objective is how can vehicles support drivers more – up to autonomous driving? For many years, driver assistance systems like ABS are used. Regulatory pressure to achieve a ratio of 95 g/100 km CO_2 [7], lead to the search for new innovative solutions. This is were the service green light prediction comes into play.

In the solution in Darmstadt, a tablet computer in the vehicle displays the upcoming traffic light with a corresponding "green phases prediction". Using this information, the engine control will be able to identify and adjust to the "right" speed for a personal green wave. Thus, emerges the concept of a cruise control for ecologic driving through the city, which leads to substantial reduction of exhaust emissions and fuel. For the first time, this system was successfully implemented on a test track in Darmstadt and tested by the automotive industry *(Figure 2)*.

The current test field can be used via an app on a tablet in test drives with conventional vehicles. Therefore, the traffic data can be used for further research and development.

Another interesting service is supporting drivers who are looking for a parking space. This entails the transparency over availability to prevent pointless searches and driving directly to a free parking spot. New kinds of sensors in street lighting offer the possibility to cover big amounts of parking spaces with optical sensors.

Especially the combination of green phase prediction and targeted search for parking spaces can lead to a significant increase of traffic flow in cities like Darmstadt. In the future, this service could be connected with smart measuring stations, for instance on street lighting, which collect additional information.

By enhancing the traffic flow, our solution bears its part in helping to contribute to the 20/20/20 goals of the European Union (20% reduction of CO_2 and other greenhouse emissions, 20% reduction of energy, 20% increase of renewable energy by 2020) to reduce the CO_2 emissions and to reach the EU climate goals [8]. But even more our solution is a first step enabling citizens to use urban data in real time.

In the future, this service could be combined with intelligent measuring stations, which collect additional environmental data like CO_2 levels, temperature or noise.

An option to enhance the traffic data is the creation of a mobile sensor network with vehicles for garbage collection, cleaning, grit or emergency which collect data on dense traffic or road traffic bottlenecks. With this sources of information an exact situation of current traffic could be deducted in real time. These enriched data could be valuable for companies driving their fleet in the city, logistic specialists and many more.

3.2 A Cockpit for the Mayor

Digitalisation is not an end in itself. Citizens and local companies expect from the smart city clear advantages, which are directly linked to the digitalisation. Data platforms as the communication infrastructure for cities need to result in real-time information and relevant recommendations for actions. In the city of Bad Hersfeld in Germany, the mayor uses to this end the solution [ui!] COCKPIT. Its dense user interface are graphic tiles which display individually selected indicators in real-time. For Bad Hersfeld these are as free parking places, noise pollution, weather conditions at the open air theatre and air pollutions, e.g. fine particles.

For [ui!], the primary aim has been to provide a platform for cities that enables them to integrate public legacy data with new data to deliver smart services. The COCKPIT is a visual output from the data enhanced with the open urban platform. With the transparency it offers, it ensures efficiency in different functionalities of a city, and has the ability to connect all corners of a city together to create services that benefit the citizens. The platform is open and flexible in analyzing data to offer services that best suit the city's requirements, while avoiding vendor lock-in.

The data platform makes it possible to not only to map data graphically but also to combine different measurement points with each other. An analytical evaluation is carried out as well – this way the noise measurements citizens carry out with an app can be displayed on a map in order to sensitise for areas with perceived high noise pollution. An evaluation of the measurement data is conducted with the so-called event stream component: Data are evaluated and displayed in different colours for a fast overview, see *Figure 3*.

The modular structure allows for individual rules to be formulated – for instance the city's administration can be alarmed in case of rising levels of particle matter and other air pollution. Combined with the various measurements, connections within a city become more apparent and ongoing smart city actions can be seen in context. An example of a live [ui!] COCKPIT is available online [9].

4. Data integration across domains

The solutions outlined above are made possible with an open urban real-time data platform. Such a platform enables data integration among various domains as well as the match-making of data. In the case of the platform UrbanPulse, this characteristic is enabled by the [ui!] CONNECTOR technology.

With UrbanPulse, [ui!] has in constant cooperation with city partners developed a real-time sensor data platform, which follows the visions of an open urban platform outlined by the EIP SCC.

UrbanPulse is a cloud based platform developed for urban data. It contains a highly scalable architecture for data processing and analysis, with a specialised connector framework for the simple integration of sensors and other urban management systems. Overall, Urban-

Figure 3. Bad Hersfeld [ui!] COCKPIT

Pulse offers a completely integrated access to urban sensor data from different domains on the basis of smart services. Thus, UrbanPulse combines the diverse data sources of a city, to better visualise and understand them in order to react better to the needs of the city. Urban administrations, companies and citizens use the information UrbanPulse processes, compiles and makes available, to optimise their individual decisions and enhance their digital services and processes.

As a platform solution, UrbanPulse offers interfaces to various communication standards. This way new data sources can be integrated in a simple and economic manner to deliver real-time data from different relevant sensors and management systems.

Figure 4 provides an overview on the architecture of UrbanPulse. The data source layer, indicates as an example different sorts of data sources, which can be connected with the platform. UrbanPulse's interfaces are highly scalable and support various simultaneous connections. A messaging system distributes received messages to the application layer, which contains the core module of the platform. This consists of a number of storing, analysis and so-called Complex Event Processing modules. The modules of the integration layer (outbound interfaces) are responsible for the data distribution and provision, for instance via the standards HTTPS, Secure Websocket or AMQP. Building on this layer, all kinds of applications, administration tools and services can be run, which use real-time events or historic data sets.

Each UrbanPulse module functions as a so-called micro service, which offers special functions for the overall system. The interactions between the modules is realised with a bus system that allows for asynchronous communication. This approach allows for a distribution of the platform over a number of instances and therefore to scale, depending on the necessary resources. Therefore, UrbanPulse is suited for a small pilot project as well as for the real-time processing of sensor data from a whole city.

5. Integration of heterogeneous data sources

For the integration of diverse heterogeneous urban data sources, [ui!] offers a number of connectors for various open as well as proprietary interfaces. With a connector, often, the heterogeneous data sources locked in a certain domain can be enabled to send data to UrbanPulse. Each [ui!] CONNECTOR is a modular application, which makes it possible to integrate even data sources with specific interface requirements or existing grown systems, so-called legacy systems. A bi-directional connection is not necessary. The connectors enable the transmission of urban data in real-time from big amount of information, management and sensor systems to UrbanPulse.

Event data received from the UrbanPulse interface is first reviewed and then forwarded to the event storage, the event processors and the analytics modules. The entire system is event-based and the Complex Event Processing module is used for the analysis, aggregation and creation of events on the basis of the urban data. This event analysis takes place due to the definition of so-called virtual sensors. Virtual sensors can be created automatically on the basis of pre-defined operations or registered manually. The pre-defined operations enclose standard operations such as minimum, maximum, and the average of the considered measurement points from different sensors of a category. Likewise, it is possible

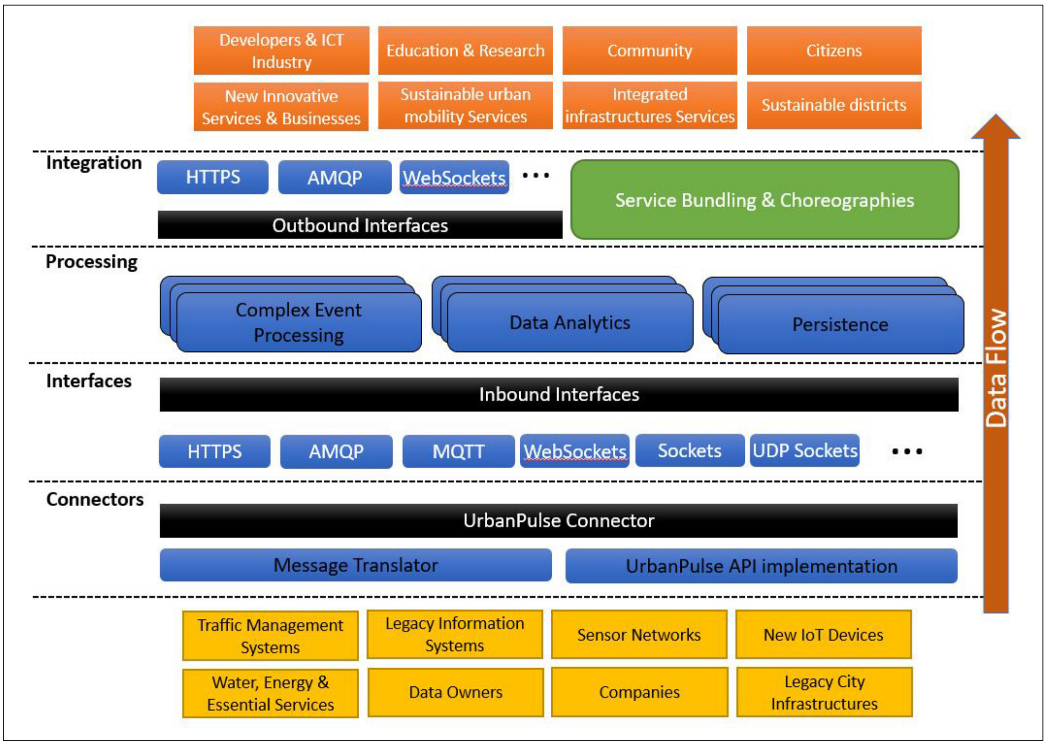


Figure 4. Architecture UrbanPulse

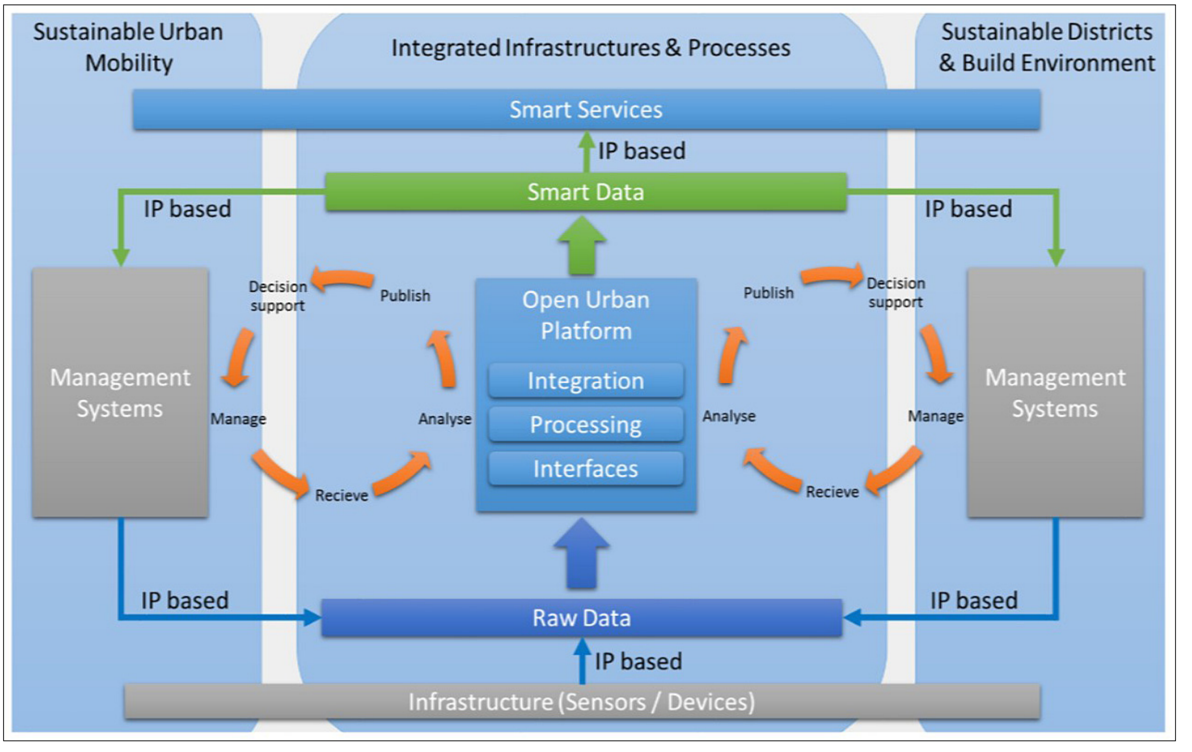


Figure 5. Open Urban Platform Ecosystem

to define thresholds for a number of areas and different time windows, from which events should be considered.

The storage module collects the different data and uses a storage cloud service to persist them in a so-called document storage. The document storage is designed in a way that allows for big amounts of data to be stored while at the same time to achieve fast response times, when longer periods of time of the historic data are inquired.

In the analytics module analysis for historic and real-time data can be developed through big data analysis.

The outbound interface connects the applications with the platform services. To ensure the reusability of the received data, all data is processed and transmitted in open standardised formats. In addition, all analytical functions are developed as a service. Therefore, the UrbanPulse interface (API) can also be considered the facade for the urban data sources and analytical services. The communication between the platform services and the application is realised with a combination of Pub-/Sub-Systems for event data and REST-interfaces for persistent data.

The management modules administer the configurations of the overall system and control the single components of the platform. A row a REST-APIs enables the administration of user, sensors, connectors as well as subscription for events.

The architecture with its different layers is aimed at mirroring the reality of urban actors: Smart Cities, which are created on the drawing board are virtually impossible to occur in Europe. Instead, cities and their (data) infrastructures are systems which have grown over decades, with a variety of different legacy systems and formats. With the connector architecture, these existing systems can be included. No systems need to be renewed. There is no need for a final decision on one system. When a city or a public company adds another system or data source, these can be connected with the platform in a very short amount of time.

6. Standards

Even though platforms, like the UrbanPulse outlined in the previous section, do not require cities to exchange their legacy systems, but rather enhances existing data sources, the adoption of such platforms in Germany is slow. To provide guidance to decision makers in cities and publicly led companies in the field of smart city and gain added value through connecting different information, a standardisation project for open urban platforms has been undertaken.

6.1 Standard for Open Urban Platforms

The challenges for cities to design tomorrow's urban environment are diverse. To be fit for the future, cities need a tailor-made mix of innovative solutions and partners, which co-develop with them. It will become a key competence for a smart city to gather, evaluate and visualize data, which stem from different sources in the city. With an open urban platform, the administration can generate added value from this data together with the citizens, solution providers and manufacturers and develop new business models.

The architecture of such a platform is paramount to include every relevant solution for the cities needs, no matter if it stems from a start-up, a research organization or an established company. This way existing legacy systems and programme can continued, while adding valuable solutions to the city, see *Figure 5*.

To demonstrate cities the composition and applications for such a meta platform, the German standardisation organisation DIN and the initiator [ui!] urban institute® have brought relevant actors to the table.

Those are companies from different fields:

IT: Deutsche Telekom, Microsoft, SAP, energy: Alliander, EnBW (SM!GHT), automotive: BMW, Continental, research: Fraunhofer FOKUS. They were supported by German cities who have already hands-on experience with smart city solutions: Bad Hersfeld, Berlin, Hamburg, Köln and Munich.

Cities and companies together worked for the creation of the standard, DIN SPEC 91357 Reference Model Architecture for Open Urban Platforms (OUP) [10] which has been completed in December 2017. The DIN SPEC fosters the mutual understanding of the market players through the common understanding of a catalogue of terms and supports the interoperability of systems. The standard presents suitable IT architectures, interfaces for data exchange and operation models, exemplifies various future-oriented use cases and includes references to already existing norms and standards in the field of the smart city. Cities and communities can use the standard to connect their existing projects and solutions and promote digitalisation in their city. Thereby, a marketplace for services can develop, which citizens, administrations and companies can use. Applications are possible, for instance, which enable the communication of vehicles and traffic lights or navigation services which detect routes with the combined geo data of cities in real-time.

An important stream of work for the standardisation project has been the work of the European project ESPRESSO [11]. Its objective is to build a common framework for smart cities [12].

6.2 Standard for Integrated Multifunctional Humble Lampposts

As the field of traffic showcases, good old lampposts can serve as locations for sensors and enhance the environment for use cases such as parking and automated driving. Especially, because they are a ubiquitous infrastructure in any city and are connected to electric grid. Recent years have made more effective LED lighting and adaptive lighting solutions more popular [13], the EIP SCC Initiative "10 million Humble Lamppost" [14] builds on these developments but wants not only to enhance the lighting functionality of street lighting but integrate sensors and actors in the masts. It makes the lamppost multifunctional as value added services become possible.

In the field of integrated multifunctional street lighting, the worldwide first technical standard was published in 2016 as a so-called DIN SPEC 91347 "Integrated Multifunctional Humble Lampposts" [15]. The objective was to leverage street lighting as a key component of smart cities and communities.

The core of the standardization project are 14 digital use cases, which demonstrate how cities and communities can profit, when they seize the current opportunity: not just replacing old lighting with LED but creating a component-based system. Meeting the demands and challenges of modern cities with targeted new functionalities. With sensor technology for traffic monitoring as the basis of automated driving. With Wi-Fi routers for public internet access. And with charging stations for electric vehicles.

Other possible sensors can detect parking spots and traffic, collect environmental data and enable event based light control. With the acquired data, new services for citizens and municipalities as well as new business models for start-ups and companies can be created.

The consortium initiated by [ui!] and DIN consisted of lighting manufacturers as well as IT companies and start-ups.

6.3. Preview on Standard for Urban mobility data collection

To add another piece of the puzzle in the use case traffic, the latest standardisation project is DIN SPEC 91367 with the working title "Urban mobility data collection for real-time applications" [16].

A consortium of car manufacturers and suppliers, IT companies, start-ups and cities has come together to create an umbrella standard for mobility data collection in urban areas which does not neglect synergies with existing urban platforms (see Section 6.1) or street furniture such as integrated multifunctional lampposts (see Section 6.2).

7. Summary

The experience with cities like Darmstadt have demonstrated an important factor for success of smart city actions.

Each city sits on a big amount of data, tracking if systems work and analysing some data for very specific purposes. Reusing and repurposing existing data across different domains is key to create value for the city and their citizens. When collected and stored data is made accessible through an open urban platform it can be combined with other data, used for predictions or enable real time services for citizens and companies who move in the city every day.

"Smart city" does not automatically mean a costly decision for a technology solution, which is binding for a long time into the future – a decision most officials delay due to imperfect information, missing best practices or unclear budgetary responsibilities between departments.

Standards, such as DIN SPEC 91357, 91347 and upcoming 91367 can support decision makers with needed additional information. Technologies such as open urban platforms adhere to the fact that smart cities do not start on the green field but in the complex infrastructure of legacy systems of cities. [ui]'s mission is therefore to support making cities even smarter.

Author

PROF. DR. DR. E.H. LUTZ HEUSER has been in the business of industrial research for more than thirty years. As CEO and CTO of [ui!] the urban software institute, he has developed successful business models to allow for efficient 'co-innovation' between industry, communities, and service companies.
[ui!] – the urban institute® is a leading software and consulting company as well as a business incubator for Smart City solutions in the areas of sustainable urban mobility, low-emission traffic, integrated multi-functional street lighting infrastructure, energy management for urban districts and integrated infrastructures. The customers are cities, communities and metropolitan regions, further municipal and private companies. With the support of [ui!]'s strategic consulting and products, the customers achieve their ambitious climate, mobility and energy goals as well as the development and operation of a digitized infrastructure for the Smart City faster, more sustainably and efficiently. The company is located in Germany in Chemnitz, Darmstadt, Walldorf and Berlin, as well as internationally in Australia, Singapore, USA and Hungary. The headquarters is in Chemnitz, Germany.
Lutz's interest is to connect those with great ideas with those who can execute on them. His vision is inspired by the fast-growing opportunities in what is being called the 'Future Internet', and he strongly believes that the 'Internet of Services' is a game changing megatrend which will allow for significant business model innovation, largely changing the way business has been done in IT.

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