Dezember 2017

DIN SPEC 91357

ICS 35.240.99

Referenzarchitekturmodell Offene Urbane Plattform (OUP); Text Englisch

Reference Architecture Model Open Urban Platform (OUP); Text in English

Modèle de référence de l’architecture pour une plate-forme d’urbanisme ouverte; Texte en anglais

There are various procedures for developing a DIN SPEC:
This document has been developed in accordance with the PAS procedure.

Gesamtumfang 56 Seiten

This DIN SPEC has been developed and approved by the authors named in the Foreword.

Preisgruppe 99
www.din.de
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Foreword

This DIN SPEC has been developed according to the PAS (Publicly Available Specification) procedure. The development of a DIN SPEC according to the PAS procedure is carried out in workshops and does not require the participation of all stakeholders.

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0 Introduction

0.1 General observation and context

Cities are facing the digital transformation as any other organization in the world. The difference is that a city is not a single entity and even the city administration is only part of a much larger ecosystem within the city limit. Therefore, a collective and cooperative approach between various local stakeholders is required to harvest the full potential of the new digital era. Urban data has become a resource of high interest for a number of use cases, namely for urban mobility, energy efficiency, safety and security, as well as climate change and health.

The good news is that quite a large pool of urban data already exists within the various urban infrastructures. The downside is that these infrastructures operate quite independently with little to no integration. Thus, harvesting the urban data has become a cumbersome and difficult task, especially due to the fact that interesting use cases such as autonomous driving in the city or measuring environmental data at various hot spots in the city are not owned by single infrastructure operators but rather require a collective approach.

The European Innovation Partnership on Smart Cities and Communities (EIP SCC) has identified the need for an approach of more integrated infrastructures, which share urban data for re-use and re-purposing it in new use cases. In 2015, the Memorandum of Understanding "Towards Open Urban Platforms" has been initiated by the EIP SCC and since then signed by a large number of enterprises and a related "Letter of Intent" by cities. The intent is to create an open and aligned approach towards harvesting the urban data by avoiding proprietary and thus single vendor dominated infrastructures. Instead, a federated and open approach to exchange and share data for mutual benefits both social and commercial is envisioned.

It is also important to stress the fact that European urban regions are dominated by rather small and medium size cities and thus lacking the Mega Cities and Mega Metropolitan regions often referred to when considering Asia and America. Thus, the challenges of European cities are to find affordable, scalable solutions, which can be tailored to their needs and size as well as having a pluralism of available solutions encouraging the engagement of local providers, SMEs, and start-ups.

The digital transformation of enterprises is often referred to as the 4th industrial revolution. As the word revolution indicates this new era means changes not only on a technological but also on an individual, political and society level. Social acceptance will therefore be next to the technical soundness one of the key factors for quick adoption of digitalization and the new business opportunities. Open Urban Platforms, which are aggregating services and data, act as a central technical urban infrastructure, since horizontalization and the interconnection of services and data are required to tackle successfully the above mentioned use cases. The term open refers specifically towards a design principle, to use open standards and interfaces to guarantee compatibility and interoperability with other systems and other urban platforms.

Other important elements are data governance and data ownership of urban data. If data is the new raw material of the 21st century, how can it be harvested to the benefit of society and citizens creating wealth and prosperity within the urban environment? The design principle of "openness" will create the foundation for these social benefits but needs to be well-aligned with the commercial and financial benefits for those who provide the data as well as for those who create value through new smart services.

Today cities face the situation that digitalization provides a new digital overlay infrastructure on the existing ones, a variety of new services and even more data. The question arises, how to control, manage, work, and provide these services and data. Hence, cities require a logical digital framework like an "urban platform" which aggregates all the different services and connects the data.

The EIP SCC has identified the need to act and established a lead initiative based on the above-mentioned MoU to work on a city needs-led approach. Organized by the Greater London Authority, a group of European cities have collectively created a common specification on how they assume the digital transformation and the harvesting of urban data should be addressed. This specification has served as input for a supply-side driven effort to develop a reference architecture for open urban platforms. The reference architecture should help to address the needs addressed in the specification as well as allowing for a federated and standardized way to exchange and use urban data across the different urban infrastructures.

In 2016, a group of enterprises, cities, and the Fraunhofer group FOKUS came together to underpin the importance of the EIP SCC lead initiative by creating a DIN SPEC consortium to extend the technical view of the reference architecture with the above-mentioned topics of data governance, data provisioning, and how to create an integrated digital urban infrastructure.

0.2 Why a Reference Architecture?

The intent of the Reference Architecture and its belonging design principles is to provide cities and communities that wish to implement Smart City & Communities initiatives a truly mission and vendor agnostic approach that will result in an enhanced interoperable, standards-based architecture and implementation which is specific to a mission when their specific city context is applied. In addition, this Reference Architecture can be used with existing architectures to plan for improving interoperability maturity and functioning of an expanding technology solution for smart city initiatives. This mission and vendor agnostic approach is meant to provide key elements and concepts needed to be addressed to make these resulting solution architectures interoperable.

A common theme among the definitions within the world regarding the term Reference Architecture is that the primary purpose of such a Reference Architecture is to guide and constrain the instantiations of logical and solution architectures. In addition, a Reference Architecture should:

— provide common language for the various stakeholders;

— provide consistency of technology implementation to solve problems;

— support the validation of solutions against a proven Reference Architecture; and

— encourage adherence to common standards, specifications and patterns.

In general, a Reference Architecture is an authoritative source of information about a specific subject or mission area that guides and constrains the instantiations of multiple architectures and solutions. The Reference Architecture as presented here provides the key elements, aligned to several other EU initiatives and worldwide standards regarding Reference Architectures. It will at least contain a generic yet integral approach including business, infrastructure, data, applications/services, security and performance domains, to which the concepts of interoperability and standards, are applied. The EIP RAD (EIP Reference Architecture Document) addresses various target groups, where not all chapters and elements need to be deeply understood by all readers and users. Both documents have some common target audiences, mayors of a city, the city manager and its policy makers, the administration that need to implement parts of an urban platform and the purchasing department that want to tender solutions. Whilst in many cases current Smart City and Standardization activities are led by bigger companies and big or even mega cities, the reference architecture can be used also in smaller sized cities or even rural areas.

The two-fold approach on infrastructure and open urban platform of the EIP SCC was mirrored by DIN with a DIN SPEC (PAS) process. Following the EIP Humble Lamppost initiative, the DIN SPEC 91347 was published to describe the new role of streetlights as “integrated multi-functional Humble Lampposts – imHLa”, in March 2017. This document complements the standardization of integrated urban infrastructures.

1 Scope

This DIN SPEC (PAS) provides a reference architecture model Open Urban Platform as an integrated data exchange platform in the digital infrastructure of a city or community in the sense of a “match-making” platform.

This document

— offers a catalogue of terms and definitions to unify the language used in this complex interdisciplinary context;

— creates a systemic comparability, which enables the interoperability of systems;

— defines of open interfaces (also known as API), to upload and download data that is their provision and usage;

— clarifies licensing models for open data that is free-of-charge as well as chargeable access and

— provides an overview of current and for this area relevant valid norms and standard in a coherent manner.

This document does not specify requirements for data storage or data processing.

This document is aimed at decision makers, procurer, planner as well as manufactures and operators. Planners are supported for orientation and selection and design of digital urban infrastructure. For decision makers, most importantly in municipalities, the significance of urban data for the digitisation of public space shall be clarified and its provision facilitated.

This document deals with the relevant data privacy aspects; with reference to the respective current legislation.

Essentially, this document describes the usage of so-called urban IoT (internet of things) data for existing and especially to be developed services.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

2.1
open data
data sets provided by public authorities and public enterprises to the general public

Note 1 to entry: Often, this term is also used to define the usage of the data sets as “free of charge” using an appropriate open data license agreement. Open data is open if the provided data can be processed and used by anyone and for any purpose. In general, Open data shall adhere to criteria such as “timeliness”, “as close as possible to the data source”, “publication under an open license” such as CC BY 2.0 which was published by the Creative Commons NPO and allows sharing, replication and modification of the data even for commercial purpose.

2.2
open interfaces
interfaces characterized by the fact that the way in which signals are transmitted to or read from an interface is described

Note 1 to entry: Protocols, in turn, describe the rules for interaction with interfaces. Their description is easily accessible to all interested parties and that they can be used and further developed.

2.3
open standard
publically available documentation i.e. as document(s) and/or description(s) enabling multivendor interoperability

Note 1 to entry: Such document(s) called (technical-) specifications, being developed by a community of companies, consortia or Standards Development Organizations (SDO's) for the sake of interoperability among products and systems of different companies.

2.4
quasi standard
product or solution provided by a company having become widely adopted by users

Note 1 to entry: Quasi standards are commonly called standards.

2.5
Internet of Things
IoT
intelligently connected devices and systems to leverage data gathered by embedded sensors and actuators in machines and other physical objects.

2.6
Smart Data
(big) data enriched by analysis, interpretation and by linking with other information

Note 1 to entry: The huge amount of data and especially urban data will become one of the most important resources in the next years which is mandatory to engage with the upcoming challenges of urbanisation and climate change. The mentioned huge amount of data or big data can be analysed and combined with other data to gain more insight about what's happening and will happen in urban space. Following the definition given in the final report of the "*Smart Service Welt*" project from Acatech, the mentioned Big Data can be enriched by analysis, interpretation and by linking with other information to become Smart Data. Based on Smart Data knowledge can be generated which is the basis for new Business models and so called Smart Services.

2.7
Smart Service
result of digitisation which enables consumers to configure and to buy individual bundles of products and services based on their needs

Note 1 to entry: Smart Service consumers can expect the right combination of products and services everywhere and every time. Smart Service providers therefore need to understand the customers' requirements and be able to analyse the huge amount of data which will result in Smart Data. These Smart Data can be used by a Smart Service or sold on a digital market place.

2.8
Urban Platform
system that facilitates the exploitation of city data and intelligent monitoring and control of infrastructure and assets in cities, and that enables new and improved services (both for public and private ends and organizations)

Note 1 to entry: Open Urban Platforms, although the term may suggest otherwise, are not concrete off-the-shelve products. Rather they can be seen as platform of platforms, consisting of existing and new elements and evolve over time. We define An Open Urban Platform as a local implementation of a logical architecture that integrates (previously) siloed city infrastructures, data platforms, and services, from different domains within both public and private spheres. To put it more simple, urban platforms integrate IoT enabled infrastructure and assets in cities, make it possible to operate and collect and (re)distribute/use data from these and other sources, and make these available to applications.

Note 2 to entry: Consistent with EIP SCC an Urban Platform is characterized here as follows:

a) The implemented realization of a logical architecture/content/design that brings together (integrates) data flows within and across city systems;

b) exploiting modern technologies (sensors, cloud services, mobile devices, analytics, social media etc.);

c) providing the building blocks that enable cities to rapidly shift from fragmented operations to include predictive effective operations, and novel ways of engaging and serving city stakeholders.

2.9
Open Urban Platform
OUP
urban platform that uses open standards and interfaces to guarantee compatibility and interoperability with other systems and other urban platforms

2.10
European Innovation Partnership on Smart Cities and Communities
EIP SCC
EU initiative to foster the field of Smart City throughout Europe

Note 1 to entry: The EIP SCC gathers together initiatives for meeting the EU's climate targets for 2020. In the areas of sustainable urban mobility, neighbourhood energy efficiency and integrated infrastructures, it has not only established networks in the form of "action clusters", but also has developed and tested innovative solutions as flagship projects as part of the Horizon2020 programme. One of the lead initiatives is the "1 000 000 Humble Lampposts" network, which is working on the introduction of integrated multifunctional street lamps in Europe and has provided great stimulus for the specification DIN 91347.

2.11
integrated infrastructure
infrastructure designed for re-use and re-purpose infrastructure data for multiple services and thus optimizing the overall return on investment

Note 1 to entry: Integrated infrastructure is used as integrated urban infrastructures using IT systems and connect them via the Internet. Integrated infrastructures serve as "systems of systems" for cities to obtain, analyze, and use urban data particularly required for any cross-domain service.

2.12
capability
extent and content of what a city or community does to execute its mission and deliver services that meet the needs of citizens and other stakeholders

Note 1 to entry: It is an abstract representation of what is needed to produce an outcome by an organization or other human collectives — along with goals and metrics for that outcome.

2.13
anonymity of a subject
fact that the subject is not identifiable within a set of subjects

Note 1 to entry: The anonymity set is the set of all possible subjects.

3 Concept of Open Urban Platforms

3.1 General information

Until recently the infrastructures of a city were often developed and provided through stand-alone (silo – vertical) systems, to support scenarios via dedicated services. In many cases the interworking with other scenarios and services is not planned and not possible. To leverage the opportunities of digitalization and the new overlay of a digital infrastructure, enriching smart service interworking across domains in combination with data analytics is required. This interworking across multiple urban infrastructures requires a coordinated approach avoiding that the different management systems are all dealing independently with the same issue over and over, again. This situation calls for a new integrated infrastructure, which helps coordinating the different infrastructure systems within a given city and complementing it with the developing Internet of Things, namely the urban sensors, which are rapidly deployed. This coordination will be provided by so called "Urban Platforms". Such an urban platform focuses primarily on the local demands and is therefore uniquely bound to the city or region, where the urban data resides and the services should be provided. In addition, the exchange of data with other platforms and also the composition of components within the platform shall be possible, which could also require smart data modelling. Thus, such an urban platform needs to follow an open design approach, e.g. with open interfaces, supporting open standards for exchanging urban data and supporting new urban services in a future-proof way, i.e. extending the scope of the Smart City services over time by an increased use of digitalization.

This however does not mean that all services and their logic shall be moved towards a single platform, rather than having a "System of Systems" approach, where the open urban platform interconnects the various existing management systems, easily. This means, that dedicated domain specific systems are still required to operate the related urban infrastructures and shield complexity. To provide this "System of Systems" like approach it requires openness on all levels as a core principle. The platform is connecting systems of different domains and enabling cross-domain smart services to be established. Different actors will have different roles depending on specific use cases.

3.2 Characterization of Open Urban Platforms

Urban Platforms facilitate the exploitation of urban data and intelligent monitoring and control of infrastructure and assets in cities, to enable new and improved services both for public and private sectors. For now, urban platforms specifically focus on the integration of IoT enabled infrastructure and assets in cities, enable re-use and re-purposing of urban data from these sources by combining them with other urban data from other sources, and make these available to applications, smart services, and other management systems.

Consistent with the view of the EIP SCC, an Open Urban Platform is characterized as follows:

— The implementation of a logical reference architecture following design principles on open APIs that supports data flows within and across city systems as well as enriching the raw data streams to generate smart data as being required by the consuming entities.

— It is exploiting modern technologies to harvest, collect, and analyse the urban data and providing the results to citizens and enterprises, e.g. sensor nodes and other IoT devices, cloud services, mobile connectivity, machine learning for analytics, publishing and sharing via social media and APPs.

— It is providing the building blocks that enable cities to rapidly shift from fragmented and isolated operation of individual infrastructures towards an integrated approach by connecting the systems via the platform, including cross-domain data analytics for predictions, forecasts, or better insight, and novel ways of engaging and serving city stakeholders offering Smart Services, both public and commercial.

This way, an Open Urban Platform should be perceived as the new digital urban infrastructure that facilitates the implementation of the overarching Smart City strategy to support the strategic goals such as climate change goals, increased energy efficiency, reduced traffic congestion and emissions, or creating (digital) innovation ecosystems for growth and wealth of the community.

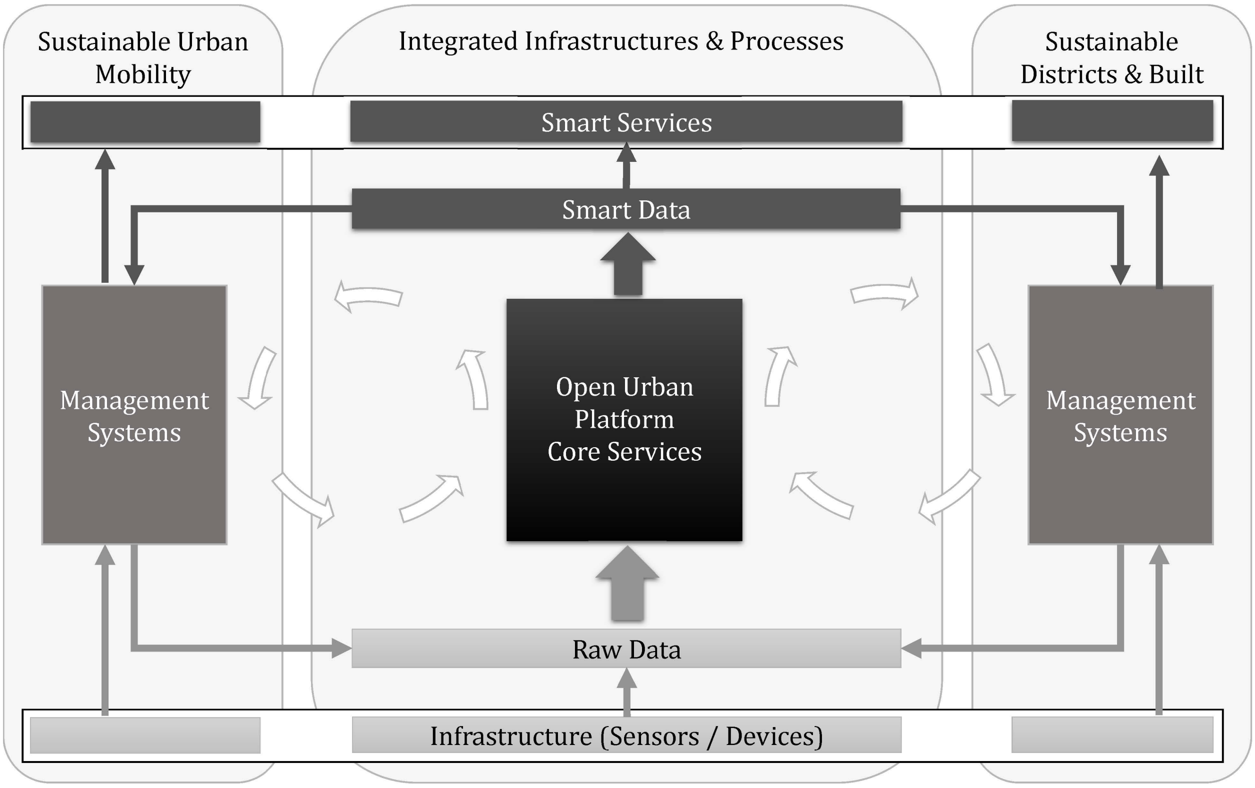

Figure 1 — Schematic picture of an Open Urban Platform

The vertical areas shown in figure 1 above describe the three thematic core areas in the EIP SCC: sustainable urban mobility, integrated infrastructures and sustainable districts & build environments. Typically, without an integrated infrastructure approach, the domains transport and built environment would barely exchange urban data as these are quite distinct domains. For example, assuming a strategic goal of increasing the usage of electrical vehicles in a city will require sharing the information regarding the need of charging among these verticals such that the distribution net can cope with it while securing the mobility capacity needed to serve the demand of the citizens. Open Urban Platforms should not be limited to these three verticals but remain open for further verticals. Certainly, the EIP SCC has demonstrated that there is a clearly defined demand for the integration of infrastructures in these domains. Other verticals such as safety & security, health or water also benefit from such an Open Urban Platform.

The Open Urban Platform concept follows four essential usage scenarios:

a) The OUP itself is a (cloud based) system based on the reference architecture (middle block in the graphic) enabling service integration (middle “block” plus a smart service on top);

b) an OUP enables the interworking with another domain, e.g. Field Component Platform (FCP), a stage on which different components like Sensors and Actors can be operated, forming a system of systems (middle and left block);

c) an OUP enables interworking between two similar systems within a city domain, e.g. management systems for traffic control or electric vehicle charging; and

d) a federated interworking between cities using different OUPs from different vendors.

From a conceptual perspective, an Open Urban Platform shall provide and integrate key IT and infrastructure components forming a digital “backbone”. An Urban Platform can be both a new system introduced to the group of management systems that secures the integration serving as a match maker or a rather flexible logical framework of interconnected systems. New services can be integrated through an open consumption interface, easily. This technical open architecture shall form a reference to compose a Smart City Urban Platform. It will allow for further extensions in the future as new domains and services will be onboarded.

Achieving this vision requires moving beyond current implementations in which the degree of integration of core subsystems within smart cities is often limited by patchworks of legacy and fixed solutions connected by custom integrations, if any. Since a variety of Urban Platforms are under discussion, this document guides towards open and thus interoperable Urban Platforms based on open interfaces and standards to enable easy and quick integration of applications, new services to be explored and data to be shared. Such an approach provides opportunities for a community of service providers and APP developers and thus reduces the risk of “vendor lock-in”, significantly.

Such a future proof hence modular platform enables continuous integration and improvement through easy addition of new services as opposed to a pure system integration effort customizing the management systems, individually. Integrating new domains, components, and systems should be simple by adding them to the existing infrastructure with a minimum of tailoring and rework of existing component interfaces.

Urban Platforms are local implementations, meaning that instances of Urban Platforms will differ per city as local preconditions and starting situation (with legacy systems in place) are different. However, many elements of these Urban Platforms will and should be reusable, especially Open APIs to IoT devices (sensors/actuators) as well as analytics applications and Smart Services, which may be customized or configured to the geographical or regional context. For instance, Smart Services for autonomous driving should work with Urban Platforms in any city.

3.3 Existing concepts and initiatives

There has been some initial work done, already. These efforts reflect the current interest and dynamics in the field of smart cities, with multiple and sometimes overlapping initiatives, and a further increase in the years to come is expected. This document provides with a common reference architecture, assisting cities and other stakeholders in positioning the myriad of existing and new initiatives, understanding how they relate to which aspects or parts of urban platforms. Furthermore, this standard provides clarity in what an urban platform should provide to be future proof.

There are currently different efforts towards reference architectures, for example the EIP SCC MoU, the OASC effort in the context of FIWARE or the Internet of Things–Enabled Smart Cities Framework (IES-City), which was launched by NIST.

One observation is that these efforts are lacking a standard to refer cities and suppliers to, which can serve as a common ground. While the EIP SCC MoU remains an open stakeholder approach, others are more restrictive and require dedicated commitment to specific technologies.

While this document focuses on the overall reference architecture of Open Urban Platforms and related open API characteristics, the detailed specification of individual components will be left to existing standards or best practice. This is in line with the view of the EIP SCC and the European Commission, who has chartered the ESPRESSO Consortium to explore these standards in more detail. The ESPRESSO consortium developed a common language/shared vocabulary and a city information and indicator platform which can be adopted by cities.

A number of challenges is addressed:

— IoT and in general M2M communication covers a wide field of possible applications and devices. Each purpose of use can have very different requirements and it is impossible to cover all those requirements with one standard in particular because of possibly different framework conditions like e.g. legal frameworks, existing applications etc. As a result, we need to contextualize the IoT requirements. Best example is the use of Smart Meter data in Germany that has to adhere to the BSI Data Protection Schema, which is only valid for Germany.

— Developing standards for a Smart City environment is currently a very dynamic process. Several Standard Developing Organizations (SDOs) are considering standardization projects in the realm of urban data platforms. However, tangible projects have yet to be launched. As a result, this document serves as a first draft to an International standard related to open urban platforms.

— An OUP shall integrate legacy systems and a wide range of different technologies, especially in the IoT device arena. This requires an open and vendor neutral approach allowing for diversity rather than single vendor solutions.

4 Ecosystem of an Open Urban Platform

4.1 General information

Since each city / region constitutes an individual ecosystem or is part of one, it requires a dedicated digital infrastructure and transformation strategy. The OUP is a master piece of the digital transformation of cities towards smart(er) cities providing the basic infrastructure for new smart services across a wide range of sectors and domains. While a significant amount of data will be provided by urban infrastructure operators, both public and private entities, there will be also more and more data provided by IoT devices of citizens and enterprises. Thus, the OUP is a mediator among a wide range of stakeholders, which also shall ensure appropriate governance, roles, and responsibilities.

In Clause 6 different use cases of OUPs are presented, each of it may lead to a different business model. The nature of the OUP should be independent of who operates it but governed by common rules. The EIP SCC lead initiative on OUP has specified such common rules. This standard will therefore focus on how to support different business models through technical and commercial governance as well as related roles and responsibilities.

4.2 Business models

As in any other urban infrastructure, cities and communities shall specify the business model on how to operate the OUP. As of today, there are no regulatory frameworks on how an OUP shall be operated beyond those known for any Internet-based software system.

Therefore, the OUP shall support different business and operating models and should not pre-determine this by the way it is designed. As operating an OUP is a new requirement for local governments and related urban infrastructure operators, business decisions regarding investment, budgeting, and operation are required.

Next to budgets and financial aspects, operational processes across the different organisations and (re-) skilling the workforce to either operate or at least connect to an OUP need to be established.

Some cities and communities have already hired a Chief Information Officer (CIO) or even lately a Chief Digital Officer (CDO) to kick off digitalization processes within the administration and across the different urban stakeholders. The OUP serves as the foundation for digitalization processes within a smart city and should therefore be directly linked to the responsibilities of the CIO or CDO. Hereby, the City CIO/CDO should orchestrate the development of OUP with key stakeholders and its horizontal expansion across all urban infrastructures, both for digitizing the public services of local government, as also making the OUP an enabler for new private services.

Dependent of the size and power of a Smart City there are different kind of business models and operation possible to run an OUP. Therefore, an organization needs to investigate the different relevant criteria as this is city specific and not the same for every organization:

— Business Model of data provisioning: Introducing an OUP, the organization needs to have clarity if data should generate a new revenue stream. Data can be sold direct or indirect. The revenue can be maximized, or the risk could be minimized on guaranteed income. Alternatively, a strategy to enable only open (thus meant as "free of charge" can be added. The decision on the commercialization of data impacts the service level by which the data shall be provided, i.e. availability and quality of the data. This business model decision has an influence on the design and operational model of the OUP with respect to system availability, performance, and persistency.

— Business Model of services enablement: Should the organization in charge of the OUP also provide the enabled services or only enable 3rd parties to provide the services, both public and private entities. Is the OUP itself the service to offer or just the basic "plumping" for a flourishing service offering? The impact of the business model of service enablement on the design and implementation of the OUP relates to well-known functionalities for Internet service provisioning such as billing, accounting, customer relationship management, and the like. This leads almost to the distinction of an OUP for B2C/G2C services or an OUP for B2B/G2B services.

— Business Model of data ownership: Who owns the data transferred and eventually stored within the OUP? One could assume that the data created and used in the existing urban infrastructures belong to the owner or operator of the related management systems. So, sharing the data via an OUP needs to include a decision on who owns the transferred (aka copy) of the data? While this is mainly a business decision, the implication on the design and implementation of the OUP remains a technical issue. Different governance and ownership model may co-exist in a single OUP. This includes the governance on "how long" the data should reside within the OUP when provided to 3rd parties and thus, what are the operational procedures and related technical functionalities to remove data in a consistent, non-discriminatory, and non-disruptive way.

— Management Framework: According to the management framework to maximize value from city data of the EIP SCC lead initiative on OUP, cities and communities should specify a vision, strategy, and a related roadmap on how to introduce and expand the digitalization using the OUP as underlying core infrastructure. The result of this is a clear mandate of the OUP to be an integration tool for any of the sectors addressed by the cities and communities and the design and functionality should not be limited to the use of data and services in selected sectors, only. While this so called "horizontal" integration capability is mandatory for an OUP, one needs to acknowledge that cities and communities may start with a very limited set of sectors / domains to cope with the complexity. The OUP architecture, design, and implementation shall therefore support the ability to extend the OUP over time, integrating new functions and linking to other OUPs serving other sectors / domains. Extensibility is a must for OUPs. The management framework includes also the need to include the political leadership understanding and endorsing the vision, strategy, and roadmap as representatives of the citizens.

— Knowledge and Capacity: Introducing an OUP requires cities and communities to have appropriate knowledge on how to harvest urban data, both technically as well as contractually. In addition, knowledge and skills about the different characteristics of data and the implication for re-using and repurposing it are required. What kind of data is classified and in which way? What kind of data should be perceived as "raw material (aka raw data)" vs. "processed data (aka smart data)"? With respect to the operation of the OUP, is the organization capable in running an OUP on their own or is there a 3rd party operator? The latter issue should be related to similar procedures and business models when introducing new eGovernment services including issues such as IT infrastructure, data security, interface design, or user experience.

There are four types of business models on how to operate an OUP in a city:

a) **City runs an OUP on their own:** This means that the City is responsible for the whole architecture and value chain. Updates, upgrades, adoption of legal requirements and integration of the different data sources would be in the ownership of the city itself. This kind of business model would require an own department of “digital data and services” with a cross-functional responsibility regarding any public data source within the ccity. This way, the city ensures ownership and control on how data and services will be provided. Different to the existing IT departments, the department of “digital data and services” must be considered as a business line rather than a support function, as attractive digital services require cross-organizational re-use and repurposing of data, which may not always fit to existing department structures. Certainly, extending roles and responsibilities towards these digital data and services, makes existing IT departments obvious candidates.

b) **City builds an own legal entity to run an OUP**: A city-owned legal entity operates the OUP and is responsible for the provisioning of the digital data and services. This way, the offering can be further commercialized and extended both to private enterprises as well as to other cities and communities. This way, the city could benefit from the scale-up in terms of revenues and cost-efficiency. City utility companies have demonstrated the value of such a business model for other existing urban infrastructures. This way, the city keeps the control through shareholder relationship while allowing for a broad take-up of the OUP as a commercial public offering.

c) **City contracts a service provider to run an OUP and transfers full responsibility**: The service provider takes over the full responsibility about availability, performance, legal requirements on behalf of the city. The city grants the commercialization of the urban public data to the service provider under a license agreement, which defines the boundary conditions of commercialization including open data provisioning as well as licenses fees to be paid by the service provider, when commercializing the urban data. The city would not be liable anymore about the service delivery. The service provider could use the data to build new digital services and commercialize them. This way, a city will benefit from the scaling assuming the service provider operates OUPs for a number of cities and communities. Digital services may be less customized to individual cities and communities in order to leverage the scaling opportunity.

d) **Collaboration of local councils (de: “interkommunale Zusamenarbeit”) sharing the operation of an OUP**: Creating own scale-up by teaming up sounds like another worthwhile business model. Several cities and communities agree to a joint venture. The new entity would operate on behalf of the cities similar to the business model described above in section b). The major issue relates to the overall ability of the communities to collaborate and act as a team. The terms of reference will be crucial as it has to provide the necessary freedom to act, especially in cases, where individual councils disagree to the overall offerings. The autonomy of the entity and how it can manage and operate on the different urban data pools of the communities are crucial success factors. On the other hand, the councils have to decide the trade-off of owning and controlling their own urban data versus the financial benefit of sharing the entity with others. This business model is also attractive for metropolitan regions, where both larger cities and smaller communities share common interest and services such as public transport, already.

4.3 Governance

Industry and politicians have been addressing the relevance of data for the digital transformation. Some have called “data” the new raw material of the 21st century. Thus, cities and urban infrastructure providers have to consider, how they are harvesting the data and how should the data become available. A governance structure is required adhering to the overarching goals and ambition of the cities and communities.

As public data is a common good, one needs to ensure that the access to the data is non-discriminatory. The rules should be specified by the city authorities as the regulatory framework in Europe and Germany is still quite vague on this. Non-discriminatory shall not imply “free of charge” or “one fits all” but should ensure that those who have a valid case to gain access to the data, can get it. Thus, business models shall be specified as further described, below.

So far, urban infrastructures are already operated under well-defined governance structures but the related data often has not been considered as an asset by itself, which may require a different governance schema. The EIP SCC talks about “integrated infrastructures” and recommends a much closer cooperation across these infrastructures for re-use and repurposing them. “Data” will be the dominant asset to be re-used for different purposes by different service providers. Thus, an overall public data and even further urban data governance schema has to be introduced to which the OUP shall adhere to.

Transparency and protecting the public good through governance is essential to prevent abuse of power. Therefor there is a need to create transparency on the data being collected and re-used in which way by whom for what purposes. Moreover, there may be a need to monitor usage of data and services of Open Urban Platforms to detect violations and be able to act on that. Data and services need to be secured by well-known technologies as used in online shops or other related online portals and market places.

A related governance topic is the use of public space for installing future IoT devices in order to collect additional data. DIN SPEC 91347 on integrated multi-functional Humble Lampposts has addressed this issue with respect to lampposts as a means of street furniture.

The governance schema shall include also the protection of data against misuse as well as preventing unauthorized access to the urban infrastructures themselves. Again, well-known Internet security standards shall be adopted within the OUP.

Different user groups need to be addressed and related service models need to be supported by the underlying business model. Hereby, the integration of data sets from different data providers to enable new digital services is the underlying governance model. User groups to be addressed include the citizens, local businesses, public and private service operators, local and regional administration as well as the general public.

While almost any smart city strategy refers to the citizens as main target, the reality check shows that this user group has not been well addressed. Successful business models of so called B2C or G2C urban services remain a challenge and if successful then the business model at best ignores the role and responsibilities of the public administration or even contradicts existing strategies and guidelines. Thus, OUPs should provide the ability to link the different service providers and their services in a way that service provisioning is non-discriminatory and adheres to the local strategies and guidelines as set out and overlooked by the local authorities.

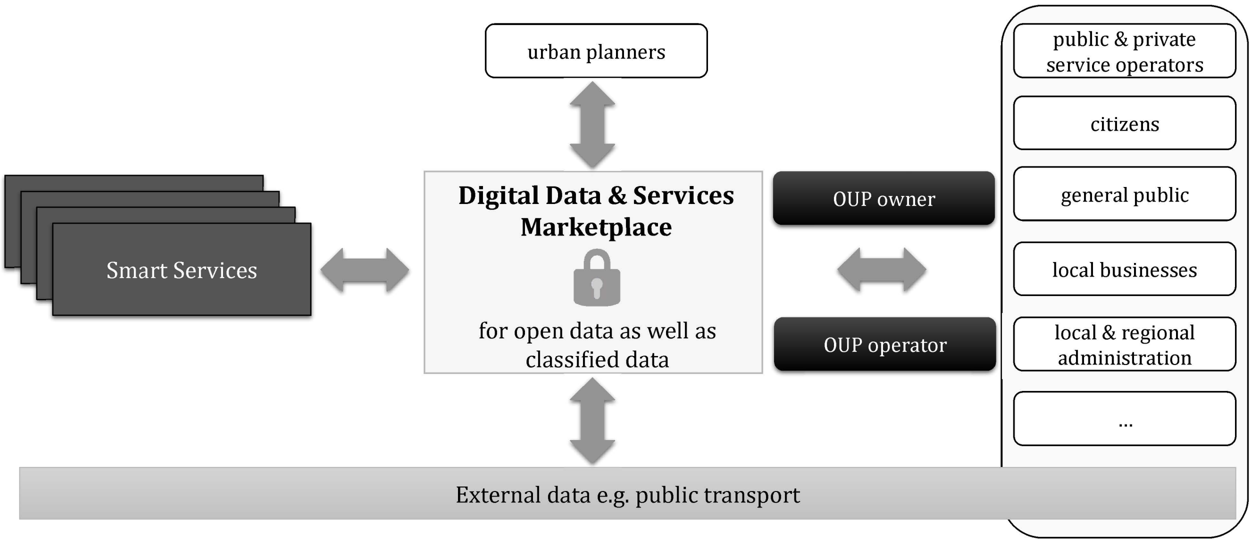

Figure 2 — Digital Data and Services Marketplace

An OUP should be a strategic tool for urban planning. First, any city-level strategy on Smart City should lead to define city needs which themselves lead to designing and planning of the digital transformation of given urban infrastructures. Thus, the OUP should provide data to urban planners as well as related analytics and simulation on how these changes will impact the overall service offering and landscape. Derived from this planning work, a coordinated way of deploying the value-added services via the Digital Data & Service Marketplace should be encouraged to re-use and repurpose urban infrastructure and minimizing the investments of service provisioning.

4.4 Roles and Responsibilities

OUPs require concrete Smart City Services considered, which drive the need for exchange data. So far, concrete use cases lead to these smart services and their implementation. Thus, budgets are mostly structured around single, so called vertical solutions rather than considering an OUP a use case by its own. As a result, implementing an Open Urban Platform requires a dedicated business justification. This business case shall be owned by an organization, who feels responsible to provide the base for a marketplace of digital data and services. This is called the OUP owner.

The OUP owner provides the trustworthiness of a non-discriminatory facilitator between the different marketplace participants, which have different vertical business needs and related solutions. The OUP owner ensures that the vast variety of IoT-related services will be enabled to use and benefit from the OUP and the related digital data and services including a related governance model.

The OUP operator is the second important role. It ensures that the OUP provides quality of service measured by horizontal key performance indicators including

— Re-use and Repurposing: An OUP shall provide the ability to promote urban data for re-use and repurposing by serving as a system that integrates easily with other existing management systems of urban infrastructures. “Sharing” is the overarching philosophy.

— Scalability: An OUP should not be limited by the number of verticals, number of participants, number of IoT devices, or number of services. Modern system architectures allow for scalable solutions.

— Availability: An OUP should be always available and requires uptime similar to other critical infrastructures. As many Smart City services offering real-time functionality, they require high availability of those data and services traded via the Marketplace and provisioned through the OUP.

— Data protection: Data provided via the OUP shall be secure in the sense that it should not be corrupted, faked or could be stolen, i.e. infringing license agreements. Thus, data integrity plays a critical role for OUPs.

— Authorization: An OUP should allow access to digital data and services only those entities and individuals, which have been authorized. Even in the case of “Open Data”, related license agreements should be signed before accessing the data.

— Authentication: An OUP shall ensure that named users can be identified and checked as the OUP is operated under commercial conditions.

— Regulatory Compliance: An OUP shall ensure that data will be stored and processed within the related regulatory framework to which the city or entity providing the data or accessing the data belong to.

Both roles can be either taken by a public entity or a private company and could be also combined.

5 System Architecture and Capabilities

5.1 General Information

Cities have different urban infrastructures, which are operated by different infrastructure providers. These infrastructures are largely operated with existing management systems. Examples are traffic management systems, street light management systems, electricity grid systems, or water management systems. In addition, more and more buildings are managed by building management systems. All in all, we constitute that a variety of management systems already exist to which an OUP shall connect to. It is consent that these systems should not be replaced as they serve to address the dedicated needs of the individual urban infrastructures. Today, these systems are mostly not interconnected with each other and rarely exchange data, already. This is the role of an OUP and thus the system architecture and the capabilities of an OUP shall address this role.

The core role of an OUP is to serve as a marketplace for digital data and services. Trading of urban data by enriching raw data with domain-based knowledge and thru integration of different data sets from different data providers is a core functionality. In addition, enabling smart services to be deployed either directly or through the interconnected management systems is the other core functionality. Finally, interconnecting different management systems of urban infrastructures allows the enrichment of existing systems by re-use and repurposing existing urban data and services exposed by the marketplace.

In the following section, a system architecture is introduced following the design principle of a “System of Systems”. Based on this core design principle, the capability map introduced in the subsequent section describes the generic capabilities, which are required to serve such a role followed by more detailed design principles of an OUP.

5.2 OUP as a System of Systems

While the sum of urban management systems in any given city is unique, the integration of them via an OUP will have commonalities allowing for a common system architecture. Although each city or community may have its own instance of its own urban platform, tailored to local needs, these commonalities are important, as they provide the following potential advantages:

— Urban platforms provide generic or “horizontal” services to a myriad of domain-specific or “vertical” smart city use cases. Urban platforms prevent reinventing the wheel and building the same common services for each and every use case or vertical domain. Urban Platforms allow multiple use across different vertical domains in a unified and transparent way by taking advantage of existing networks, components, sensors and other IoT devices.

— Urban Platforms facilitate the exploitation and sharing of data and possible synergies across different use cases and vertical domains. Urban platforms provide stakeholders, respecting security and privacy, access to urban data, with clearly defined access rules, commercialization rules for re-use and repurposing, and semantics independent of the dedicated data formats allowing all kinds of data sets to be shared among the marketplace participants.

— Urban Olatforms can be shared by a group of (smaller) cities and communities, making the use of an Urban Platform more financially feasible for smaller cities and communities.

— Urban Platforms following this OUP standard will allow service providers and data consumers to use the urban data (more) *consistent* in terms of data access, data security, and data provisioning.

— Following the agreed capabilities as described in the section below, suppliers can develop urban platforms as a more standardized product, which can be purchased by multiple cities and communities and thus provide an economy of scale.

However, to turn these advantages into reality, a prerequisite is to have a common understanding and vocabulary regarding the general system architecture by suppliers, cities and operators.

Also, this common system architecture needs to be *agnostic* with respect to city, community, technology, product and supplier. The system architecture should be usable for all urban platforms as characterized here, no matter how it is implemented and by whom. Also it needs to be mission, project and vendor agnostic. It shall be able to act as a real reference for cities and communities, and other relevant stakeholders, that have the wish to realize a comprehensive solution.

The common reference system architecture that is presented later in this clause, is a shared logical “bigger picture”, that makes clear which components are fulfilling which parts of the Urban Platform.

Also this reference architecture does not necessarily imply that any Urban Platform should be a single implementation, a single physical system, or that it should be a single vendor that is supplying a city’s Urban Platform. Collaboratively, different system components form the overall provisioning. The single common system architecture is a shared logical ‘umbrella’ that makes clear which systems and solutions are fulfilling which parts of the Urban Platform.

Thus, the Urban Platform may be considered to be a “System of Systems”, which connects different management systems and uses itself different system components. Therefore, the Urban Platform does not replace existing systems, but instead will provide the “glue” to create synergies between such existing and future new systems.

In addition, the Urban Platform does not stand alone. In most cities and communities there will be other systems that are not part of the urban platform but which will provide (data) input to the Urban Platform, like e.g. administrative systems that provide citizen data — if allowed by privacy rules. Also, other systems may make use of services and data provided by the Urban Platform, for example fleet management systems using traffic information provided via the platform. Also, the urban platform can interact with other urban platforms in other cities, depending on use cases that require such interaction.

To support the required interaction and interoperability that characterize Open Urban Platforms, following standards is of key importance. These standards may include communication protocol standards, emerging Internet of Things standards and data exchange or data ontology standards, which in the case of smart cities are still to be further developed.

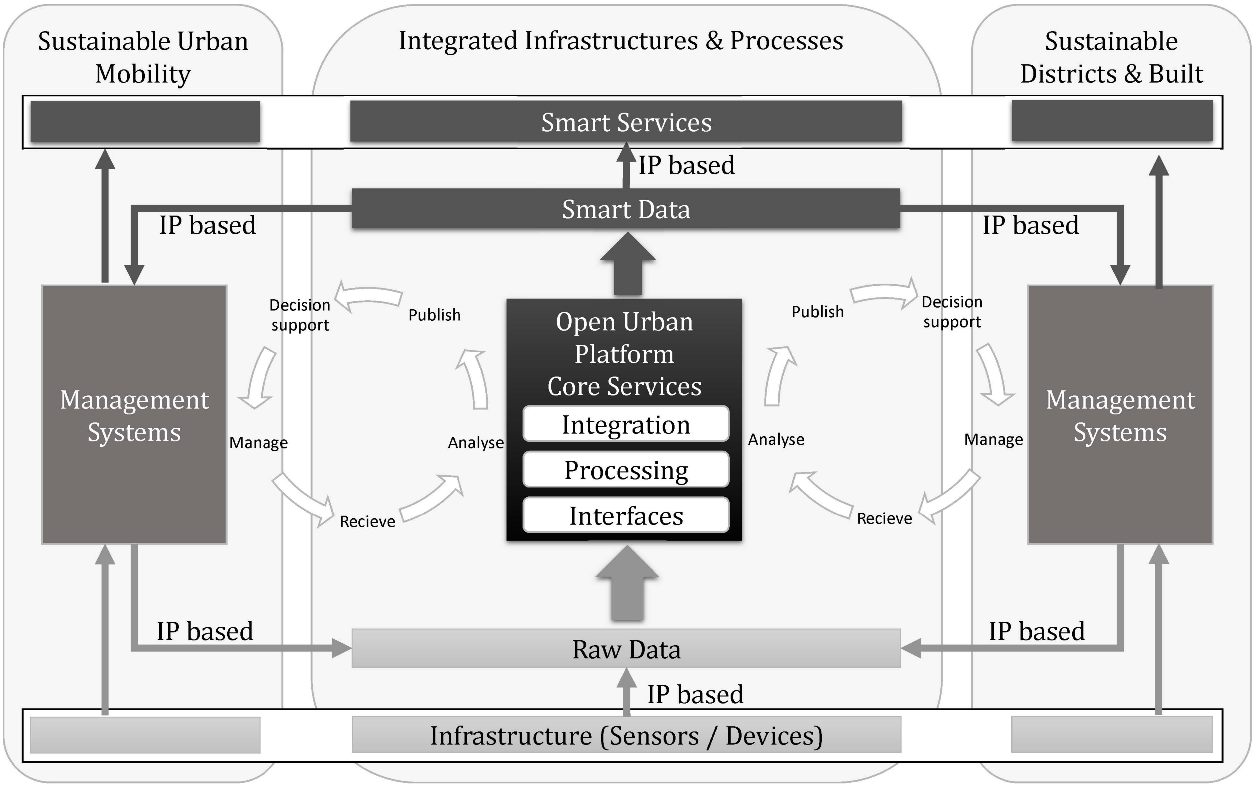

Figure 3 — Framework for the Reference System Architecture of an OUP

Figure 3 shows the framework in which the reference system architecture exists and is highlighting the specific focus of the EIP SCC on the three vertical priority areas **Integrated Infrastructure and Processes, Sustainable Urban Mobility, and Sustainable District and Built Environment.** Other domains shall be supported by the OUP, equivalently.

Adopted from the EIP-SCC Open Urban Platform reference architecture's vision and derived design principles:

— The reference system architecture for Open Urban Platform should be considered as a common "umbrella" that allows the structured positioning of existing architectures and associated implemented solutions. The reference system architecture should support re-use of existing proven architectures, which are typically aimed at specific layers such as the IoT device communication layer or the data storage management which are more detailed and specific.

— The reference system architecture follows a layered approach for decomposition of logical clusters, each of it can be defined either separately or integrated into an overall platform architecture.

— Capabilities are the center element of the architectures to ensure that a common ground is easy to be found; each capability cluster is represented by a single layer within the reference system architecture.

— The reference system architecture should allow and certainly not hinder incremental, iterative evolutionary approaches for implementation of open urban platforms, typically starting by focusing on existing opportunities/pain points and then incrementally further expanding the platform over time.

— Open Urban Platforms should be based as much as possible on open standards, preferably based on large-scale deployments. Especially, between the various layers in an Open Urban Platform, open standards are promoted to support flexibility and prevent e.g. vendor lock-in.

— The reference system architecture should enable a variety of Open Urban Platforms. In general, the reference system architecture must be agnostic to technology, market structure, implementation method, vendor and products.

— The reference system architecture should enable cities to use and deploy various (combinations) of modules in the Open Urban Platform, assuming they follow the logical clustering of capabilities.

— The reference system architecture described in this document shall remain valid for as long as possible, even if technology and standards change — making it as much as possible future proof.

— Any infrastructure approach (edge-based, on premise, cloud-based, mix of all) shall be possible (i.e., the reference system architecture is agnostic to infrastructure deployment scenarios)

— Privacy and Security principles are integral part of any Open Urban Platform and their architecture (often called Privacy and Security by Design)

— Urban data is currently often under-utilized, and then often in a single vertical application. Despite synergetic opportunities, data is hardly used across vertical domains. An important focus area of urban platforms should therefore be on harmonization of data from different domains and data providers for an increase re-use and repurposing of existing urban data and infrastructures.

— Urban Platforms should facilitate the publication of (Linked) Open Data as well as the provisioning of license-based data usage. The terms of reference of the data provider should determine the availability and usage and been properly addressed by the OUP.

— An important focus area of urban platforms should be on “collaboration” and “sharing” processes across domains vs. “single entity/domain processes”.

It is explicitly acknowledged that already various very sound and useable system architectures have been delivered globally, which are widely adopted, and which adhere to the principles as described above. We explicitly do not want to replace any existing reference system architecture but rather want to complement existing work by providing a reference system architecture that is focused on open urban platforms.

In addition, further recommendations have been identified:

— When designing and implementing an open urban platform, adopting/reusing existing public infrastructures should to be considered;

— cross-city usage of OUPs should be as seamless as possible to allow for economy of scale regarding new urban services as well as seamless access in case of people and business moving from one city to another;

— IoT-based use cases provide the highest demand on the use of urban platforms — communication bandwidth and general platform capacity needed to run smart city initiatives will most probably increase in the forthcoming years. Real-time use cases will become the dominant business cases for introducing and extending OUPs;

— use cases or “Smart City services” that are based on the Open Urban Platform are typically not aimed at a single target citizen, but at a “community of citizens”. OUPs should therefore stimulate “match-making” capabilities and internetworking.

With the above in mind, in the following clause provides a common reference system architecture, in what is called a “capability map” for Urban Platforms, derived from the Open Urban Platform reference architecture of the related EIP-SCC lead initiative and the H2020 project ESPRESSO.

5.3 Capabilities of an OUP

5.3.1 Capabilities explained

Capabilities in this context represent what a city or community does to execute its mission and deliver services that meet the needs of citizens and other stakeholders. A capability is an abstract representation of what is needed to produce an outcome by an organization or other human collectives – along with goals and metrics for that outcome. Capabilities are implemented by processes, services, components, or even human intervention. A well-known and widely accepted approach is to implement these capabilities by "services" which can be composed to higher level, often called "value-added services". Within a Service oriented Architecture (SOA) different existing components such as databases and compute resources are encapsulated to services which can be orchestrated to more complex services leveraging an Enterprise Service Bus. By following a micro service based architecture, complex services are composed of small units which can be easily added and replaced or even shut-down if need without affecting the whole system.

Capabilities are structured and grouped in a "capability map". The capability map is used as a tool for planning and assessment of which capabilities are already in place, which ones need further development or are lacking? Capabilities have become a widely used tool to help understand the implications of business drivers, clarify priorities, and plan further investments.

For example, a common capability is financial management — all aspects of managing a city's cash flow, financial asset management, and reporting. Financial management is a conceptual capability, and the actual implementation uses people, processes, information, and technology to provide the required output — in this case, effective management of a city's finances. Moreover, financial management may be implemented differently from city to city or even within different parts of the same city; different cities or areas within a city might outsource certain functions or use different technology.

From the above it should follow that Capabilities do not correspond directly with single organizational processes. Nor do they refer necessarily to single technological or physical solutions. Instead, capabilities are a more abstract way of describing what a city or community should be able to do, while remaining agnostic to how exactly the capability is implemented.

5.3.2 EIP SCC capability categories

All capabilities that are relevant in the context of an Urban Platform have been grouped in a number of categories. Capabilities within categories have similar characteristics and reflect common needs or behavior. Interaction between different capability categories should be standardized, making one category agnostic to the way other capabilities are fulfilled or implemented. Put differently, categories are preferably more like black boxes to each other, requiring input and providing output, without the need to know or having a dependency on the specific implementation. In case of changes or innovations in one category, this allows for less impact on other categories and hence for more flexibility.

Within the scope of the EIP SCC lead initiative "Towards Open Urban Platforms", ten capability categories have been specified as described in table 1.

Table 1 — Capability categories

No.	Capability category designation	Description
0	Field Equipment/Device capabilities	Capabilities that enable the external environment (field equipment, devices, IoT) to be sensed, measured, and controlled.
1	Communications, Network and Transport capabilities	Capabilities that enable the interaction and thus the exchange of data between devices and field equipment between themselves and with applications residing on some “backend systems” often referred to as “management systems”.
2	Device Asset Management and Operational Services capabilities	Capabilities that enable the delivery and assurance of the assets supporting the device communications and integration including positioning capabilities.
3	Data Management and Analytics capabilities	Capabilities that enable the use of urban (field) data by applications. It will include core data management and life cycle (e.g. ingest, assure) related capabilities, as well as capabilities to analyze, share and publish (open) data
4	Integration, Choreography and Orchestration capabilities	Capabilities to manage, choreograph and orchestrate processes and services in support of system integration and human computer interaction.
5	Generic City and Community capabilities	Capabilities that enable the deployment of generic (non-city or community specific) capabilities with respect to the roles and duties within any given urban environment.
6	Specific City and Community capabilities	Capabilities that enable the deployment of specific city/community capabilities. Here within the EIP SCC, with three main streams: Sustainable Urban Mobility, Sustainable District and Built Environment, and Integrated Infrastructure and Processes
7	Stakeholder Engagement and Collaboration capabilities	Capabilities that enable cities and communities to engage and collaborate with a large variety of stakeholders and to manage the strategic goals agenda and roadmap. Here, within the context of the EIP SCC, the EU climate goals reflect the needs of such capabilities around energy efficiency, GHG reduction, and wider use of renewable energy.
8	Privacy and Security capabilities	Capabilities regarding integral Privacy and Security apply across physical sites and assets, devices, networks, data, application and people. Compared to physical security, cyber security is aimed at protecting confidentiality, availability and integrity in the digital context, by applying a myriad of tools and measures, including identity management, authentication and (both functional and data oriented) authorization, intruder detection and auditing.
9	Common Services capabilities	Capabilities that support other Capabilities regardless of the layer in which the Capability is found; these are more generic technical capabilities, not city-related program or goal specific.

5.3.3 EIP SCC capability map

When translated into a capability map, categories can be ordered to reveal their general interdependencies (meaning that one category can only exist if the other also exists, one relying on the outcome from the other, directly or indirectly). E.g. category 0 provides a foundation for category 1, category 1 for 2, and so on. However, please not that this does not imply that categories may only interact with directly adjacent categories. Although the latter is more likely, it is also possible that direct interaction exists between more remote categories. In adddition, the map reveals that categories 8 and 9 have a generic nature, interacting with all other categories in an equally likely way.

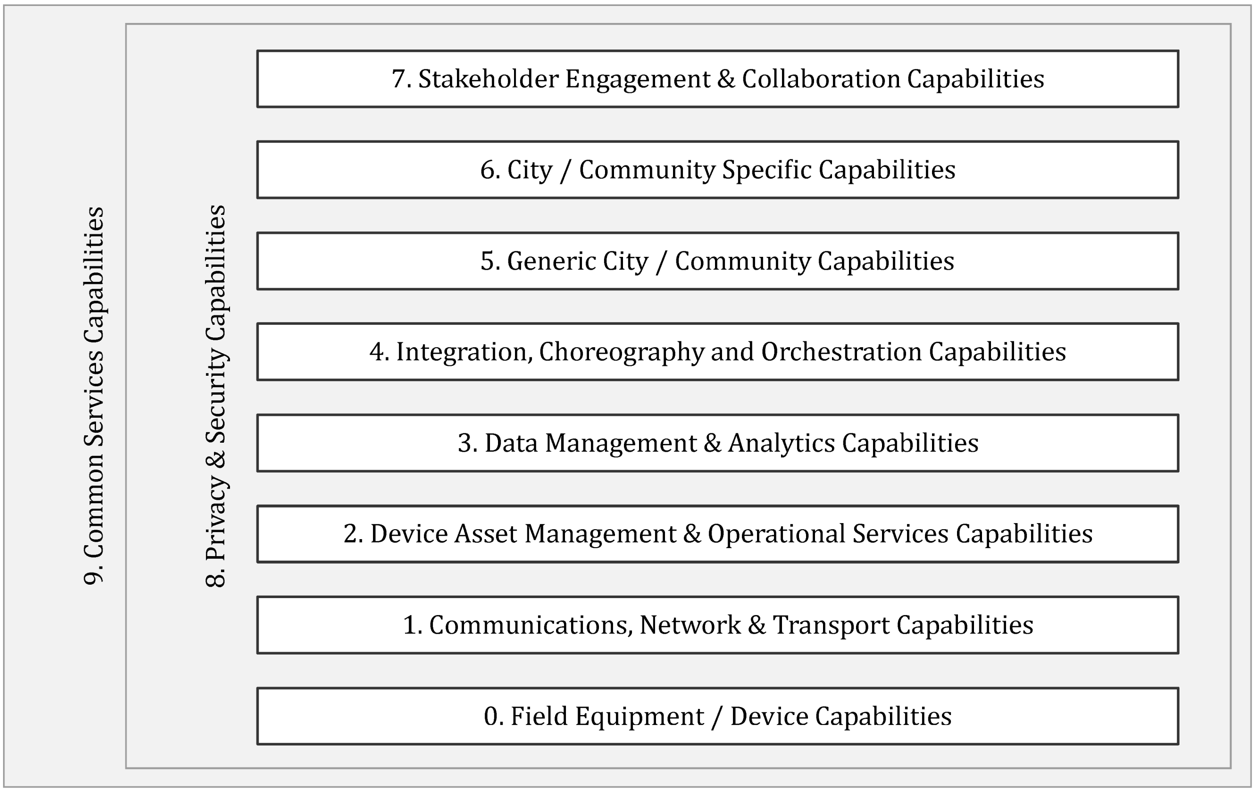

Figure 4 — EIP SCC Urban Platform Capability Map

For each category a set of capabilities has been identified. These are given in table in A.1.

5.3.4 Enhancements of EIP SCC Urban Platform Capability Map

The EIP SCC Urban Platform Capability Map outlines three mainstream capability clusters in category 6 “Specific City/Community Capabilities”: Sustainable Urban Mobility, Sustainable District and Built Environment and Integrated Infrastructure and Processes). These mainstream capabilities are the result of a prioritization of subjects within the related European Innovation Partnership, given its charter. In addition, further city specific capabilities can be added to category 6 of the framework to cover a broader scope of application areas that are likely to become applicable to Smart Cities. The following table 2 describes such additional capability clusters. The list, however, does not claim to be exhaustive. It merely highlights the necessity for each city and community to specify the capabilities needed to execute its mission and deliver services that meet the needs of citizens and other stakeholders.

Table 2 — Extensions to Category 6: Specific City/Community Capabilities

Category	No.	Capability	Description
6	6.4	Public Security — Risk Detection — Prevention — Crime Investigation — Disaster Management — Event/Incident Management	All measures provided by authorities or enterprises to protect and secure citizens, visitors, economics, infrastructure, and environment. Collection of data from city infrastructure and environment (events, traffic management systems, emergency services, private and public-sector security systems, etc.) to prevent threats. Identification of risk sources through data mining techniques, artificial intelligence, trend analysis, etc. Coordinating police and judiciary forces in operational planning and execution for a safe environment. Communication in emergency situations between public administration and citizens in both ways.
	6.5	Health and Welfare — Assistant living — eHealth services — Tele-medicine services — Pollution reduction	Set up and operate an administration framework that is easily accessible, efficient, inclusive and free of discrimination to foster social citizenship. This includes a connected health care environment with medical services for all citizens, clinical and non-clinical. Engage with affected parties and provide adequate social welfare services. Ensure access for everyone and respect social standards as well as confidentiality and privacy regulations.
	6.6	Research and Education — Research Infrastructure — Lifelong learning — Distance learning — Digital content — Augmented and virtual reality services	Create and manage a research and learning infrastructure to attract and develop talents and enable a lifelong education. Create an innovation climate to develop and maintain the basis for future prosperity. Set up an education framework to enable citizens to learn anywhere and at any time. Make education available for all citizens, across all ages and at acceptable costs. Keep learning content current and demand oriented.
	6.7	Urban Economics and Commerce — Economic Planning and Development — City Marketing — Innovation space & laboratories	The capability to create sustainable economic growth and prosperity. Increase a city`s competitiveness by fostering the growth of new and innovative businesses while protecting existing ones. Increase in-city-attractiveness through strong and vital commerce infrastructure (retail, tourist offerings, guided tours, shopping experience, consumer targeted) and strengthen purchasing power. Increase awareness of attractive offerings through a seamless digital customer experience (involving consumer, business, and administrative institutions). Create a functioning and transparent labor market.

In addition to the already specified EIP Privacy and Security capabilities, further data protection capabilities related to the personal data of the individual user, should be considered and consequently added to the framework scope in category 8 (Privacy and Security Capabilities) (see table 3). This is closely related with and complementing the capabilities 3.9 (Data Privacy Protection) and 3.10 (Data Security Management) according to table A.1 which have a stronger focus on the technical aspects of privacy data management (see also 7.3).

Table 3 — Extensions to Category 8: Privacy & Security Capabilities

Category	No.	Capability	Description
8	8.6	Personal Data Protection — Informational Self-Determination of the individual — Privacy Statements and Transparency — Best Practices sharing — Audits — Deletion of Data Records	All capabilities to protect the individual against unauthorized collection, storage, usage and disclosure of his/her personal data in an urban digital environment (private organizations and public authorities). Establish communication measures on customer facing websites and apps to raise awareness for data privacy and accept privacy statements. Developing and executing end-to-end data protection audits. Provide transparency where personal data are used. Establish mechanisms to de-activate and delete data records with personal data after expiration. Inform individuals about data theft and misuse of personal data.

All capabilities to protect the individual against unauthorized collection, storage, usage and disclosure of his/her personal data in an urban digital environment (private organizations and public authorities). Establish communication measures on customer facing websites and apps to raise awareness for data privacy and accept privacy statements. Developing and executing end-to-end data protection audits. Provide transparency where personal data are used. Establish mechanisms to de-activate and delete data records with personal data after expiration. Inform individuals about data theft and misuse of personal data.

These extensions to the EIP SCC OUP capability map have been identified within the creation of this standard and reflect the nature of what has been stated earlier that the capability map and thus the reference system architecture shall remain open for future enhancements.

6 Digital Use Cases

6.1 General information

Nowadays, cities already operate applications supporting their internal business process as well as customer relationships. While the next generation of digitalization of these services is referred to as eGovernment services, Smart City services differ from them as they are new and often disruptive to existing business processes. Some of these Smart City use cases can be handled by a single domain application, whilst others need access to multiple domains and/or require data from external sources. From a data perspective, the various smart city use cases are based on some general principles. Data required to execute a use case can originate from various sources, such as: a) single domain application, b) set of numerous independent domain applications, c) public data repositories and/or d) private data providers.

This represents a world of federated systems with largely distributed data sources that need to get integrated and shared with the Smart City service providers. Obviously, the larger the number of smart city use case a city wants to operate, the more federated IT infrastructure will be required. Hence, the OUP operates as a "System of Systems" with interfaces to a wide range of different IT systems, and with interactions to many market players such as data providers, service providers and data consumers.

In order to exemplify the usage of the emerging Open Urban Platform, four generic use cases are so far identified:

1) single OUP providing a central data and service repository;

2) OUP interacts with existing management systems;

3) federated OUP within a city, each providing a community of data and service providers; and

4) federated OUPs across cities for regional or pan-regional service provisioning.

One user scenario for each of the above four use cases of OUP is provided in this clause. In addition, a set of use cases from different domains are presented, which show various relevant instantiations of the platform and the underlying reference model/architecture. The use cases originate from different national and international (e.g. EU H2020) projects and involve relevant domains within a city.

6.2 Single OUP

6.2.1 Description

An OUP shall provide IoT device management capabilities to manage the huge amount of existing and upcoming IoT devices. Therefore, the OUP shall support operations like status requests, firmware update, device configuration, reboot, reset and of course commands to collect data from different IoT (sensor) devices, which populate their data directly to the Internet. Services will either listen to data streams related to these devices (pull) or will be informed (push), when either any data or a specific variation of the expected data stream has changed. Thus, the services do not have to orchestrate the different IoT devices but focus on logical events, so called complex events to happen. This is especially of interest if a large number, i.e. thousands and more, sensors send their data in parallel and they may even differ in the way how they are sending the data, e.g. different data formats. Thus, the OUP serves as a blending service for raw data input allowing the smart services to rely on the business events, i.e. smart data, rather than the technical implementation of collecting the raw data.

6.2.2 User Scenario

A city plans to deploy several environmental sensor nodes across the city to obtain fine-granular overview. These nodes provide different environmental data such as CO_2, NO_X, noise, or particle matters. The sensors might come from different vendors, using different transfer protocols and data formats. To generalize the management of the sensor nodes and to allow the reuse of the collected measurement data, the city decided to use an OUP. Each sensor node will provide the collected data via the Internet or via Virtual Private Network (VPN) solely to the OUP. The OUP will collect the data and pre-process the data against given thresholds providing events to Smart Services and APPs, when exceeding the thresholds.

A reference structure of a standalone OUP for providing the above required functionality is given in Figure 5. It includes the known layers and flows but focused on a single OUP, which is then utilized with its Smart Data and Smart Services, in order to enable the described (user) flow.

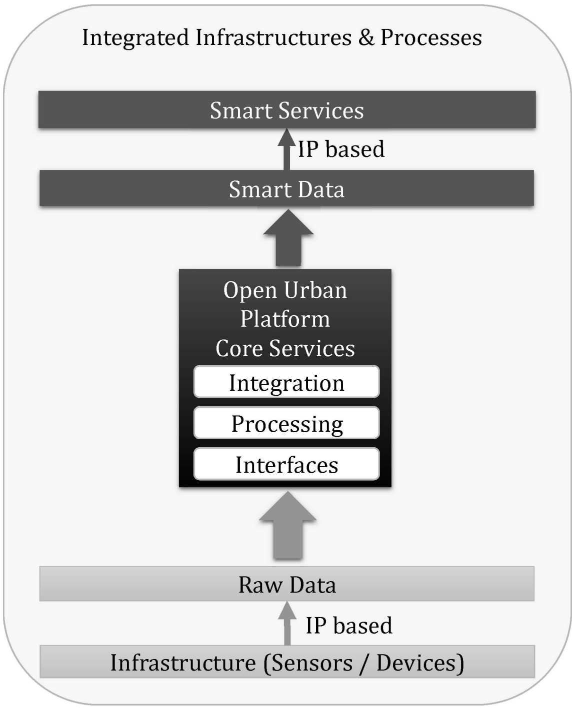

Figure 5 — Illustration of a standalone OUP

6.2.3 Implementation

The implementation of this scenario requires several OUP capabilities. The environmental sensor nodes belong to the Field Equipment Capabilities Layer (0) in accordance with figure 4 enable the external environment to be sensed. To receive data from the sensor nodes the capabilities of the Communications, Network & Transport Capabilities Layer (table A.1, 1) are needed. Of course, all the nodes must be managed in an efficient way. The Device Management Layer (table A.1, 2) provides the required capabilities. Before the received environmental data can be processed, the data itself shall be described. For this task, the OUP provides the Metadata Management (table A.1, 3.15). Now that the meaning of the data is available it can be further analysed. This includes operation such as data fusion (table A.1, 3.5) and data aggregation (table A.1, 3.6). To make the data available to consumers the (Open) Data Publication (table A.1, 3.14) capability of the OUP can be used. At the end, the resulting smart data must be consumed to create value. The Integration & Orchestration Layer (4) provides capabilities to define and select events (Event Management 4.6) to trigger the distribution of smart data (Publish Subscription & Notification Mgt. 4.10).

6.3 System of Systems (OUP interacts with other management systems)

6.3.1 Description

This use case describes how and why two or multiple systems federate with a coordinating OUP as a System of Systems. Already today, cities use multiple system solutions in different service domains from different vendors. With increasing digitization, the number of service management systems will increase as well as the need for an integrated approach. Therefore, domain systems need to allow for data exchange with other urban domains to foster synergies and enable new innovative use cases. If these systems are compliant and compatible to the OUP, they can federate via the OUP and provide a uniform access to the capabilities of this System of Systems. This way, the city avoids a complex meshed network of bilateral communications among domain systems, which bare the risk of costly integration and maintenance. Technically speaking a n-to-1-to-m system is easier to operate and maintain than a n-to-m system, i.e. without a mediator respectively coordinator system.

6.3.2 User Scenario

A city wants to improve the search of free, on street parking space, e.g. for residential parking permits. In order to avoid intensive search for free parking, which could make up to 30 % of inner city traffic, the city would like to share available parking space detected by so called smart parking sensors. These sensors are part of an imHLa system, which collects the information through sensors integrated in the lampposts. The OUP gathers the parking data and may contextualize the data in order to provide predictions, if the spot will remain available for drivers seeking for a space in the given area. The results will be pushed as smart data to a smart service, e.g. "Green Parking Guide", see figure 6, which helps to find residential parking with lowest emissions for search traffic. The smart service will be provided by some independent private entity, e.g. as part of the navigation system of a given car. Thus, data provider and service provider are independent entities connected via the OUP.

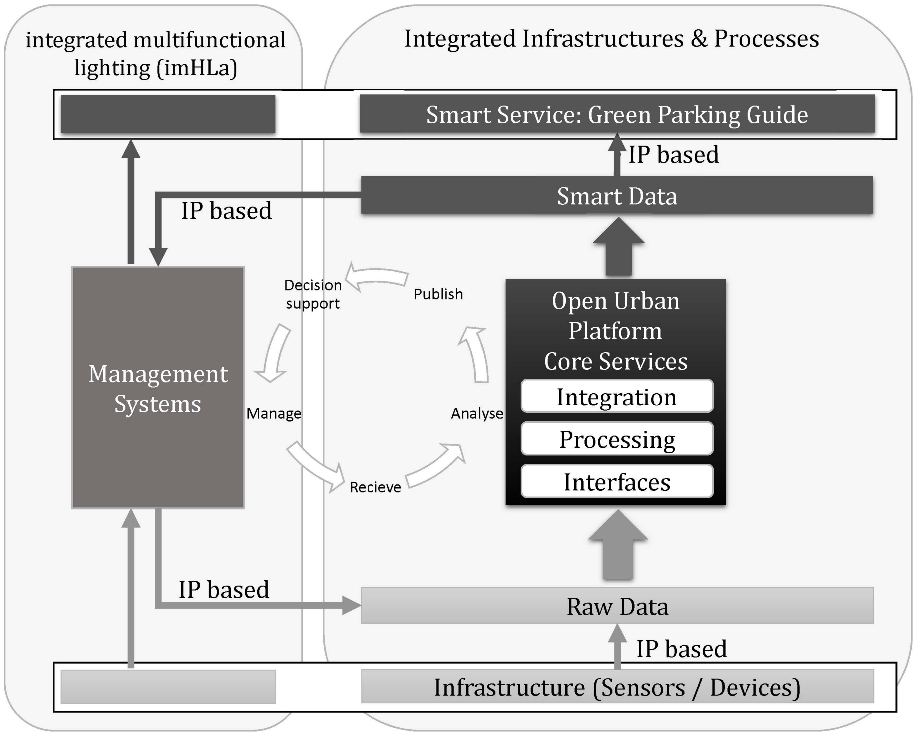

Figure 6 — Illustration of OUP as System of Systems for green parking guidance

6.3.3 Implementation

To leverage the parking information from the imHLa system, the OUP requires the permission to retrieve, analyse, and push the resulting Smart Data to the Smart Service. The received data provides the prediction of available space and can be combined with data about the car itself and the remaining time to get to the spot. Based on the result of this analysis the smart service "Green Parking Guide" will decide which available spot to be chosen, as it will be most likely available. Hereby, a constant real-time update is required, as other cars may have taken the identified spot in the meantime. To receive data from the imHLa, the capabilities of the Communications, Network & Transport Capabilities Layer (table A.1, 1) are needed. As any other data source the imHLa must be registered and monitored by using the capabilities of the Device Management Layer (table A.1, 2). To integrate the data from the imHLa and to create predictions different capabilities of Data Management & Analytics Layer (table A.1, 3) are needed. The (Complex) Event Processing (table A.1, 3.7) capability can be used to identify the current state of a parking lot while the Data Discovery capability (table A.1, 3.13) can be used to learn patterns and to predict parking lot state changes. The raw data as well as the predictions (smart data) can be described with the Metadata management (table A.1, 3.15). A User of the "Green Parking Guide" should receive notifications about the current and future status of parking lot the user intends to use. The Integration & Orchestration Layer (table A.1, 4) provides capabilities to define and select the relevant events from one or multiple parking lots (Event Management (table A.1, 4.6)) to trigger the distribution of notifications about free parking lots (Publish Subscription & Notification Management (table A.1, 4.10)).

6.4 Federated OUPs – Same City

6.4.1 Description

An OUP-based approach could lead to more than one OUP being available within a city. Thus, a federation of OUPs is envisioned that acts as a virtual single OUP but endorsing the different business and thus service relationships. As different infrastructure operators may favor different OUP systems but all are operating within the same city. Their OUP systems shall adhere to common open APIs and communication protocols, at least. For an even tighter integration a harmonization regarding the data formats has to be considered. This is particularly true when the related use cases require a real-time consumption of data.

6.4.2 User Scenario

A start-up would like to develop a mobile application that enables the multi-modal routing and integrated usage of public transport, electric mobility (including usage of energy infrastructure elements, e.g. charging stations) for the area of Berlin. The mobile application of the start-up allows a user to plan a journey by using the most convenient combination of transportation means concerning the traffic situation and public transport options.

There are two OUPs — as illustrated in Figure 7 — which provide in combination all necessary dynamic and semi-dynamic information.

— OUP-1 is operated by traffic authority of the city and holds a spatial data base with traffic information (SpatDB) of the city with a resolution of a few centimeters. The SpatDB contains also landmarks (like traffic signs, trees, road construction places, bus stations, etc.), which are used by vehicles to locate themselves with a accuracy of a few centimeters. The SpatDB in the OUP-1 (including the landmarks) is kept up to date by vehicles, which use a local copy of the SpatDB and inform about deviations detected by its sensors (camera system, radar, acceleration sensor, etc.) Additionally, OUP-1 gets information from hundreds of sensors (traffic detectors) and has a complete overview of the traffic within the city.

— OUP-2 is a (public) data marketplace operated by a private company on behalf of a consortium of the city government as well as private and public companies. The OUP-2 is provides an Open Data Portal and holds in addition to the mandatory meta-data also the data itself, which has been collected from the data sources. These data sets include public transport information (time tables, station location, delayed services, etc.) as well as information on charging stations (location, occupancy, price, etc.).

OUP-1 and OUP-2 exchange data; OUP-1 is the master of the SpatDB (including landmarks) and provides it to OUP-2. SpatDB changes are synchronized close to real-time. The same is done for traffic information.

OUP-2 is the master of public transport data (stations, etc.) and synchronizes this information with OUP-1 so that the landmarks stored in the SpatDB of OUP-1 are up-to-date.

In order to provide the service the APP requires data from both OUPs. Based on the user’s selected destination the APP requests the current traffic situation from OUP-1 and the location of bus stations as well as the bus schedules from OUP-2. In case the user intends to use an electric vehicle, the location of charging stations is also requested from OUP-2. This procedure is repeated for all potential routes until the best route is calculated.

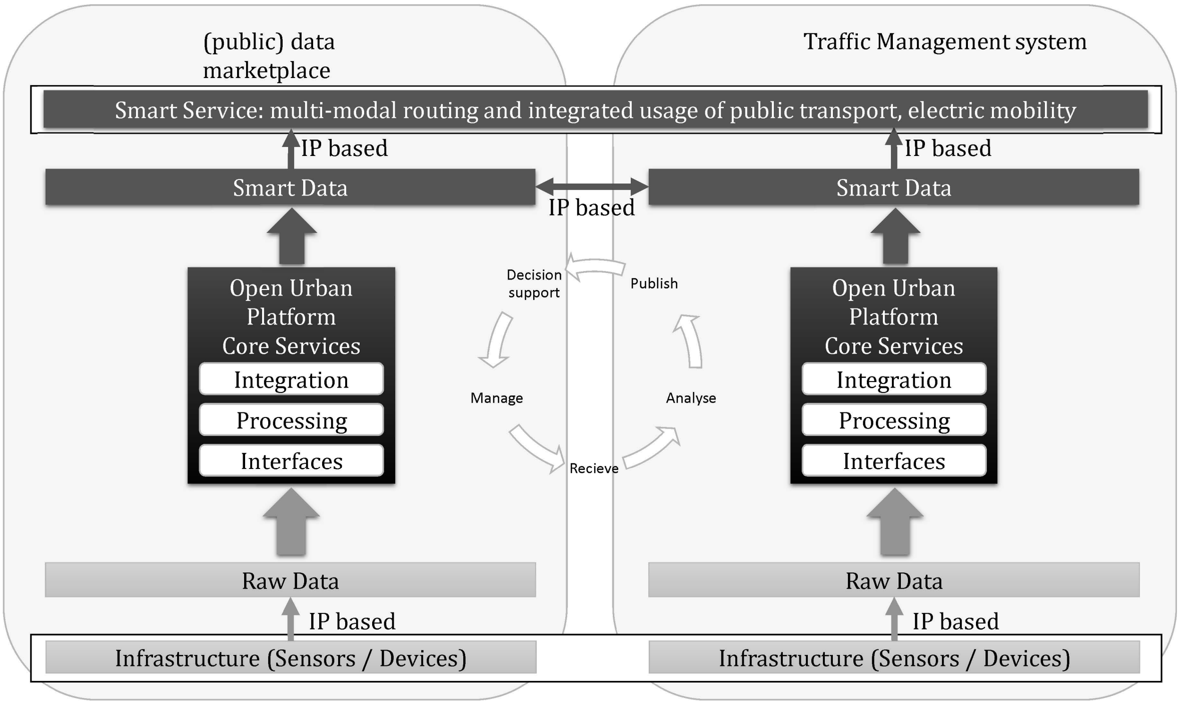

Bild 7 — Federated OUPs within the same city to support multi-modal routing

6.4.3 Implementation

The data exchange between the two OUPs and the mobile application requires the capabilities of the Communications, Network & Transport layer (table A.1, 1). To ensure integrity and availability of data the Data Security Management (table A.1, 3.10) will be leveraged. The Metadata Management (table A.1, 3.15) and Data Discovery (table A.1, 3.13) capabilities are used by the start-up to find the information required for their service. The (Complex) Event Processing (table A.1, 3.7) capability is used to identify traffic jams based on the different traffic detector measurements. The Data Exchange Capability (table A.1, 4.1) is used to translate the location information of the SpatDB to GeoJSON while the Messaging capabilities are used to provide the data to the multi-modal routing application. Since the start-up uses several open APIs of the OUP the (API) Service Management capability is used to manage the API usage.

6.5 Federated OUPs — Across Cities

6.5.1 Description

Certain smart services should be made available across different cities in a seamless and transient way, so that end users or consuming systems do not have to deal with local implementation details. Hereby, open APIs, standard protocols, as well as harmonized data formats are crucial to relieve the smart services from adapting to different aka in-compatible OUPs within the different cities.

6.5.2 User Scenario

The following use case illustrates the usage of OUPs across multiple cities. The OUP structure and relations are depicted in Figure 8, showing how Open Data harvesting is realized across various Open Data portals.

Assuming a start-up from Berlin would like to develop a mobile application that enables the multi-modal routing and integrated usage of public transport, electric mobility and different energy infrastructure elements (e.g. charging stations) across Germany. Therefore, the start-up obtains relevant data regarding the current city from the related Open Urban Platform via an Open Data Portal (e.g. daten.berlin.de). To extend their service to other cities in Germany the start-up uses the GovData.De portal and its data-catalog to lookup for Open Urban Platforms of other cities providing equivalent datasets and services required by their mobile application. The available information from the Open Data Portals and their corresponding Open Urban Platforms of Hamburg (transparenz.hamburg.de/open-data) and Berlin has been harvested by integrating their data catalogs. This way the mobile application can transparently provide services both in Berlin and Hamburg, instead of having two APPs, e.g. one for each city. Given a user opens the mobile application in Berlin to plan a journey to Hamburg. The mobile application should provide the most convenient combination of transportation means concerning the traffic situation and public transport options and availability of charging stations.

6.5.3 Implementation

Basically, the described use case utilizes the concept of Open Data harvesting, which employs RESTful calls, to share data between multiple Open Data portals and corresponding Open Urban Platforms to collect information about the availability of data. The (API) Service Management (table A.1, 4.9) capability is used to get information about open data publications available on an OUP by leveraging the Data Discovery (table A.1, 3.12) and Meta Data Management capabilities (table A.1, 3.15).

To provide the most convenient combination of means of transport, the mobile application requires data from both cities including real time information such as traffic information, public transport schedule changes and availability of charging stations. Therefore, an Analytics module which is deployed as a core service of the Berlin OUP subscribes to pre-processed events from the Hamburg OUP and Berlin OUP to retrieve real time updates by leveraging the Data Logistics Capability (table A.1, 3.8). The received data is used to continuously calculate the best route for a specific application user. The Data Exchange (table A.1, 4.1) and Messaging (table A.1, 4.2) capabilities is used to provide the relevant data from the OUP the mobile application.

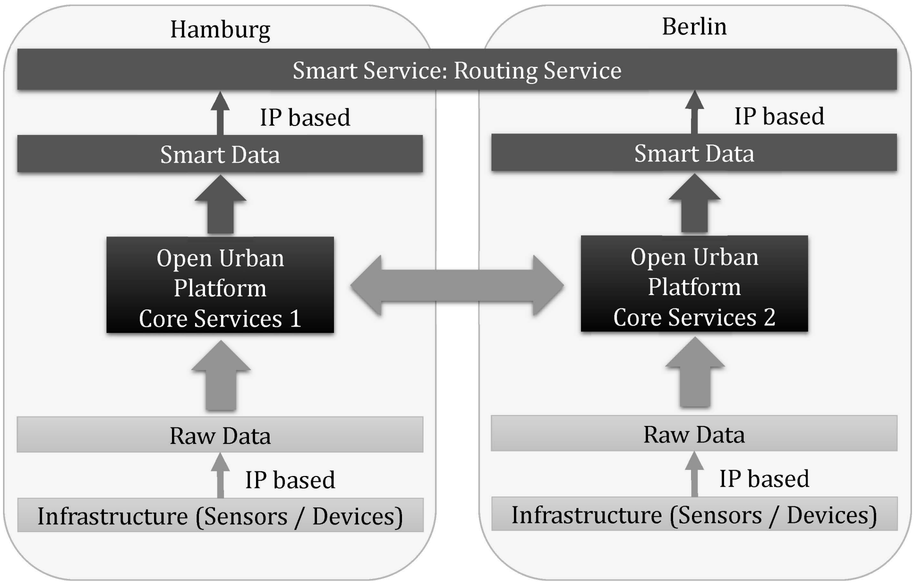

Figure 8 — Federated OUPs across multiple Cities (Berlin and Hamburg)

7 Data and Service Marketplace

7.1 General

Creating value for the users of an OUP will require that the OUP can serve as a digital data and service marketplace, where participants can provide their urban data as raw data or smart data as well as their smart services to other participants. Thus, the ability to share and trade data to enable smart services shall be supported within all layers of the reference system architecture.

First, “urban data” is still a very generic term, which can be used for many kinds of data sets as exemplified in Table 4.

Table 4 — Data sources per category

Data category	Data
Traffic	Traffic camera information
	Traffic light information
	Construction side information
	Public transport
	Car sharing information (Where is what car located)
	Public park data
	Privat park data
Public and Infrastructure	Smart Lighting Location, consumption, devices connect to street light
	Environmental data
	Citizen data
	Noise pollution
	Rental price information
	Tourism
Social media	e.g. twitter and Facebook data
	News ticker
Event data	Public events
	Private events
	Event management data
Crisis data	Fire, Water, accident, ….

Even within the domain specific definition of data, there is still a significant amount of ambiguity asking for harmonization in order to be efficiently re-used. To describe the data reference architecture, which should be addressing the above aspects, the TOGAF framework is used as guide. First, the data is described in terms of an abstract data model. Then the data value chain is described as the common data management process. Then those parts of the data value chain are described that are of particular importance, with data interoperability requirements being the most critical. This clause is concluded on data architecture by describing a number of guidelines.

7.2 Open Interfaces to Access Urban Data

7.2.1 General

The aim of an Open Urban Platforms as a cities’ infrastructure is sharing of urban data across the different services and management systems to provide a generalized access to the cities’ urban data. An OUP shall ensure the re-use and repurposing of urban data for new innovative services and to improve established decision-making processes. Furthermore, the openness of an OUP is one of the main requirements for interoperability. This clause describes the requirements and gives descriptions for the openness attribute of the interfaces. It also lists a minimal set of standards and capabilities which shall be supported by an OUP.

Frequently the attribute “open” is used in a reduced way as “free of charge” access to data. From a technical point of view the interaction with the Open Urban Platform is performed via open interfaces. Furthermore, Open Interfaces can be in place in and between the different layers of the Open Urban Platform architecture.

Depending on the stakeholders’ perspective, the openness attribute can be specified along the following questions regarding the data provision and consumption:

— How to provide data to platform?

— How to find and consume data from the platform?

— How to manage data providers and consumers?

Open Interfaces are also the key to interoperability at large. Different standardization bodies are currently working on models and frameworks to achieve interoperability. The working group of National Institute of Standards and Technologies (NIST) is currently analyzing differed Smart City and IoT Architectures like OpenIoT, Fi-Ware and oneM2M, to name a few, to identify so called Pivotal Points of Interoperability (PPI). The aim is to show up overlaps, gaps, and commonalities of the different architectural layers.

The following interoperability spots are defined:

— Interoperability of multiple OUPs:
  Open APIs should allow OUPs to access data and services from other OUPs as any other participant, i.e. management system or smart service. Hereby, we envision service level agreements between the OUP owners.

— Interoperability of Smart Service and an OUP:
  An OUP should provide an easy consumption of data and services by smart services to allow for easy re-use of urban data and services. Hereby, we envision service level agreements between the smart service provider and the OUP owner.

— Interoperability of existing Management Systems and an OUP:
  Existing management systems act as prosumers of urban data and services. Thus, we envision bi-directional service level agreements between urban infrastructure operators and the OUP owner. With respect to data provisioning the urban infrastructure provider states the quality, integrity, and availability of its services and data.

— Interoperability between Sensors and Devices with an OUP:
  In the future, more and more independent IoT devices will directly interact with OUPs. It is envisioned that the IoT device owners provide a service level agreement to the OUP owner, which states the quality, integrity, and availability of the service and data.

Those interoperability spots can be mapped to interfaces in the different layers. Focusing further, the **Raw Data Interfaces** layer, the **Data Processing** layer and the **Data Integration layer** of the high-level architecture are shown in Figure 9.

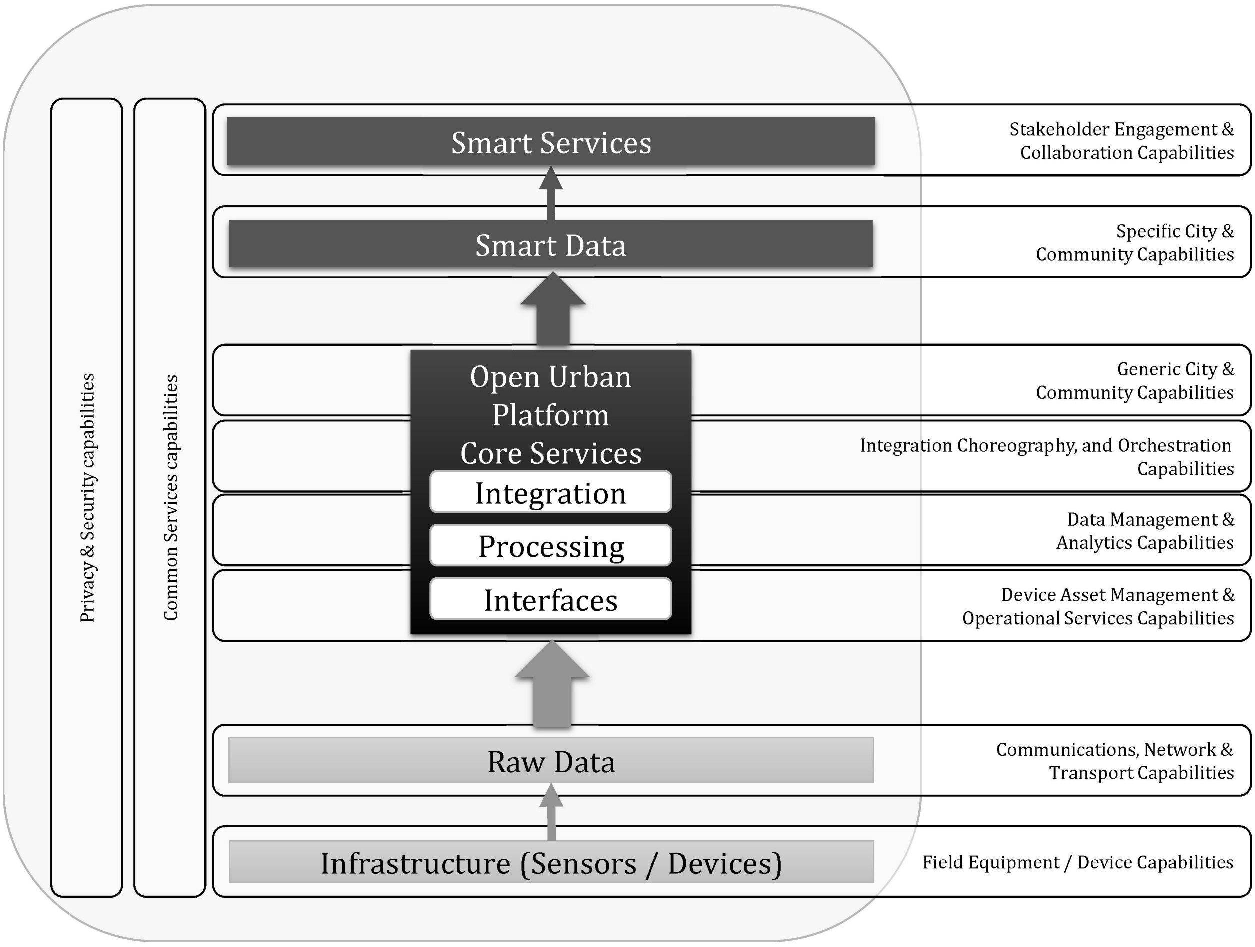

Figure 9 — Open Urban Platform layers

7.2.2 Raw Data Interfaces

Management systems are the prime source of existing urban data, which they have generated and used to fulfill their dedicated capability. This data could be of high interest to other participants of the digital data and service marketplace. To re-use and repurpose this urban data, the OUP needs to access to the data of the management system through an API using open and/or standardized communication protocols. Any update on the data should be pushed to the OUP in near real time in order to support time critical value-added-services. If the management system itself does not provide such an API the platform shall support the development of wrappers which are able to communicate with e.g. proprietary interfaces in order to receive and transform the desired data (e.g. Scoot Traffic Management System which can be accessed via Telnet to subscribe for status information). In order to automatically retrieve the data the wrapper mentioned before shall be able to connect and login to the system and it shall run specific commands to get the data. The received data shall be furthermore transformed to an open standard e.g. JSON object message which gets pushed to an OUP afterwards via a **secured open protocol** such as HTTPS, AMQP or MQTT over TLS. Within this procedure the content of the messages has to be described in a human and machine-readable way and shall reflect the performed data transformation.

In order to manage those data sources and to identify messages pushed or pulled from the data sources a minimal set of requirements should be fulfilled by such an access point. First it should be able to manage the connected data sources of the OUP in RESTful way. That means it should be able to create, update, receive and delete resources within the OUP. Each resource should be identified by a uniform resource identifier. Regarding the submitted messages, the access point should be able to send and receive messages thereby ensuring that the content description (of the transferred messages) follows an open, human and machine-readable schema definition. Examples are XML or JSON, XML Schema or JSON Schema and ontology based approaches to name a few. The content might contain data of different formats such as JSON, XML or CSV. Each of the messages should contain the uniform resource identifier of the data source as well as a timestamp.

7.2.3 Data Processing Interfaces

Raw data often is of limited use for data consumers, which expect so-called smart data enriched and pre-processed. The core services of the data processing layer fulfill different tasks within the data processing chain and provide management capabilities of the Open Urban Platforms. Each of the services should send and receive messages from other services and applications in a RESTful way. The different services exchange data, commands and monitor related information. Data Messages can contain data of different processing stages including raw data and so-called Smart Data which is routed from one service to another e.g. the output of an analytics service gets forwarded to a storage service. As already claimed for the Raw Data Interfaces it is mandatory to support interoperability of services from different vendors. Therefore, the communication and the transferred messages must follow established standards, which describe the behaviour of each service and the access points between the different services. The transferred messages must contain a sender and receiver uniform resource identifier to support message transfers over multiple hops even to other Open Urban Platforms in the same or to a different city.

7.2.4 Data Integration Interfaces

The fast acceptance and adoption of the Open Urban Platforms as a new city infrastructure requires an open and barrier free access to the available data sets and interfaces for different stakeholders. To avoid those barriers and to enable the re-use and repurposing of urban data for new innovative services, the interfaces must be well documented and standardized. A minimal requirement is the support of a HTTPS and JSON based data propagation to accelerate the utilization of the OUPs and the development of value added services on top of the Open Urban Platforms. In addition, which transport protocol is used, the schema and the semantic of the transferred messages shall be provided in a standardized way as part of the interface documentation. Again, standards like JSON or XML and the corresponding schema should be used to describe information. In addition, an open data catalog like CKAN and a meta-data catalog like Hypercat should be provided for exposing further information about the data sources.

7.2.5 Management Interfaces

Before providing or consuming data from an OUP, some registration and configuration steps have to be carried out. To avoid any barriers regarding those tasks, the management capabilities of an OUP shall be at least accessible via HTTPS and follow the REST-paradigm. Furthermore, the API shall provide a public available, human and machine-readable API documentation based on OpenAPI, WADL or WSDL 2.0. By enforcing this functionality, the management API can be easily integrated into third party services and applications by using the documentation for automatic code generation.

7.2.6 Extended Interoperability

Extended interoperability can be achieved by using a common ontology and the concept of linked (open) data which complements the usage of open communication and transfer protocols.

Rather than trying to match data from different domains at a syntactical level — the traditional approach, the extended interoperability should be achieved by providing a common ontology, specified in the Ontology Web Language (OWL), which in turn is based on other generic or specific ontologies. These include for instance ontologies relating to persons, buildings, locations, etc. that is required such that other ontologies can be mapped into e.g. Smart City Linked Data, OpenIoT or oneM2M which provides a Base Ontology to describe messages from so called Non-oneM2M devices. That is required such that other ontologies describing (sub-)domain systems and the data being published by the systems can be mapped to the common ontology.

The linked data (using RDF and OWL) setup still allows stakeholders to contribute own ontologies describing local special data elements, whilst remaining in the overall common ontology structure. Even with tailored additions to any standard framework, one can still travel along the path of the standard's new versions and upgrades, without having to re-implement the solution or to invest other significant efforts. Meanwhile, (sub-)domain systems continue to report on their specific (sub-)domain; the common urban ontology allows these to be collated into a common picture of urban processes, actors and objects such as Data sources, Raw data, Smart Data, Smart Services and data consumers.

7.2.7 Conclusions

Open Interfaces are well documented and the documentation is available to all stakeholder.

Open Interfaces should follow the REST principles.

Open Interfaces and transferred data should be based on Open Standards.

The description of the Open Interfaces is machine readable.

The data provided by an Open API might not be free of charge, i.e. open API does not imply "Open Data Licensing".

Open interfaces are mandatory for the general interoperability of an OUP and the other systems in a city.

7.3 Data Architecture

7.3.1 Guidelines

When delivering a specific Data Architecture, the following elements should be in place:

— a clear definition of which components in the architecture will serve as the **System of Record** or Reference for master data in the Urban Platform;

— a **city-wide standard** for data consumption that all application components can rely on; and

— a sound **data value chain decomposition** of the various elements in the data model (see section 7.3.3).

The various types of data that can be managed within an Open Urban Platform can be categorized, and within that category further detailed (e.g. raw data can be time series based or non-time series based):

— Audit Events;

— Raw Data;

— Analytics Data;

— Transactional Data;

— Customer Data;

— Application Data; and

— Asset and Configuration Data.

7.3.2 Data model

The data about a city or community are a digital representation or "digital twin" of the physical, social and other characteristics of the city or community. At least there is a collation of "digital built environment" (BIM), cadaster, business index, address, "greenspace", ITS infrastructure, and utility infrastructure. This needs to bring together the indoor, outdoor, above & below ground spaces — and increasingly, "places" which exist in a purely digital sense.

Data in the SCC context can be very different and highly varied, both functionally and technically, e.g. data is mostly stored in different management systems and databases with non-uniform schemas. However, from an overall SCC view, we see common characteristics of all SCC data. Basically, all SCC data is about **urban processes** in which **urban actors** play a role, often facilitated by or with the use of **urban objects**.

EXAMPLE 1 (Person) transportation is an urban process, with urban actors like people and systems playing roles like driver, passenger, inspectors etc. using urban objects like cars, trains, trams, boats, roads, rails, stations, bridges, tunnels, traffic lights, and many more.

Typically, urban processes, actors and objects can be **composed of** or be **related to** other processes, actors and objects.

EXAMPLE 2 Transportation is a process that –depending on the instance of the process- be composed of other processes like walking, biking, driving and parking.

Likewise, an urban actor like a family (e.g. driving in a car) is composed of its family members. And an urban object like a road is composed of road segments, cross-roads, car lanes, bike lanes, or sidewalks.

Also, urban processes, actors and objects are often categorized in different **types**.

In addition, data about urban processes, actors and objects can be considered as relevant in certain **perspectives**. Examples are political, financial, legal/contractual, environmental, health, safety, technical (construction, inspection & maintenance, decommissioning), usage/operational and other perspectives.

EXAMPLE 3 An urban object like a traffic light may be complemented with data about its purchase price from a financial perspective, and data about its maintenance history from a technical perspective.

Some data may be common to multiple perspectives.

Attributes of urban processes, actors or objects may be **generic attributes** or **specific attributes per type and/or per role and/or per perspective**. Typical generic attributes are **location** and **time** related.

EXAMPLE 4 The street address or the geo-coordinates of a building.

Locations may be a specific point or may be more complex like a shape (e.g. the contours of a building) or a straight or curved line (a road segment). Dates and times are also very common, either as a point in time or as a time interval.

Depending on the process, perspective and/or spatial-temporal context, both actors and objects can play one or more **roles**. A natural person may play a role as passenger in one context, or that of car driver in another or that of car owner in the same or still another context. An object like a street light can play a role in both transportation process and from a security perspective.

A further distinction can be made about the **time-variance** of data. **Reference data** e.g. types to categorize urban processes, actors or objects, typically changes rarely (and may even be candidate for a common EU standard). Data about actors and objects are typically slowly changing, and may be considered as **master data**. In contrast, data about processes typically changes frequently, with the frequency depending on the nature of the process and the level of detail of whatever is being **monitored/measured/controlled** in the process, summarized as **metrics data**. Data in processes is often recorded in **transactional** (administrative, financial) systems or, increasingly via (real-time) **sensors and IoT devices**.

Master data is typically recorded in **registers** (catalogues). This is a class of data entities: those that need to exist once in some authoritative sense. Good examples are:

— register of businesses operating in the city;

— register of addresses;

— register of citizens; or

— cadaster — who owns what.

Each of these master data registers will have governance, stewardship, and a maintenance process. Some will be owned and managed outside the city, for example by a national authority.

There are other registers/catalogues of urban objects which are more volatile (change more often), but where the overall urban platform as a system of systems would benefit from a single source of truth:

— sensors;

— actuators;

— datasets and/or APIs available via the digital data and service market place.

These system level registers may well be provided by the standard approach within that architectural component, e.g. internet domain name resolution, media access control (MAC) addressing.

Metrics data — where a city knows what it wants to measure, this will provide additional information entities to manage. In many cases this may be set by external reporting requirements e.g. cleanliness of beaches, air quality, urban noise.

Examples of things to measure include the UN Sustainable Development Goals; the ISO, IEC, ITU, and other ‘smart city metrics’ standards; various European Commission Environmental Directives, for instance the information model INSPIRE. Work is currently on-going in various SDOs (Standards Development Organisations) to map from the goals, via the metrics to the data entities required to measure them. Examples of data items to support measurement include:

— social sustainability: response time for emergency services: calculated from incident reports;

— environmental sustainability: noise levels: observations voluntarily collected from citizen’s mobile phones; city-owned sensor measurements; or

— economic sustainability: number of empty shop units, calculated from business and address registers; supplemented with citizen observations (active reports, and indirect through mining social media).

Each city will establish and evolve its own common data model, containing a generic part and instances for each (sub)domain, including a high-level overview or catalogue of data types. The common data model provides common semantics and the capability of publish and link data in a dynamic matter.

7.3.3 Data value chain

Data shall be handled in an efficient and effective manner. This is due to the massive amounts and increasing density of data that is required and expected to run a smart city or community with an urban platform. All this data handling follows the same value chain, which is the basis for the data architecture, see table 5.

Table 5 — Data Value Chain

Part of data value chain	Activity	OUP layers	Description
Data Management	Data Ingest and Data Storage	Infrastructure, Interfaces and Processing	Access and extraction of data to collect it from any source and the management of that data transport, before it is stored in a managed manner
Data Governance	Data Cleaning and Data Securing	Interfaces and Processing	The validation and cleaning of data in such a manner that outliers and anomalies are managed within a secure data environment
Data Analytics	Data Discovery & Data Analyses	Processing	The aggregation and distribution of data for analytical purposes. Analytics and algorithms are applied to the data to enable smart services. Besides analytics, transactions, time series and vectorial data are managed
Insights Delivery	Acting on Data and Analytics, and the automation of this	Smart Data and Smart Services	Based on the provided data insights are delivered upon which services and management systems can act (take decisive action) to achieve their specific goals.

The Data Management Capabilities include all data management, governance, analytics and insights delivery activities, as a foundation to support the onward service centric and business process centric use of the data by other capabilities.

7.3.4 Data Privacy

The OUP shall provide an end-to-end security covering data security, access control, authentication, security monitoring, transport encryption from Infrastructure (Sensors/Devices), transport encryption to third party management systems and platform services. The definition of data privacy principles should be taken into account throughout the entire lifecycle of the OUP. An OUP should be designed proactive, not reactive, i.e. in a privacy preserving way from the beginning. Privacy is default and embedded. Privacy should not diminish the functionality of the system, End-to-end security, visibility and transparency should be reflected in the design as well as a user centric way.

The European network and information security agency ENISA introduced eight privacy design strategies which include data oriented strategies and process oriented strategies. They can be regarded as guidelines for platform design strategies. These strategies include e.g. policies that only a minimum amount of data should be processed, transmitted or collected (MINIMISE), and that sensitive data and their interrelationships should never be shown in plain views (HIDE). Examples for process orient strategies are related to the transparency of personal data usage (INFORM) and to the control of which personal data is getting processed by a system (CONTROL). An OUP shall implement these strategies, if personal data gets processed.

The European General Data Protection Regulation (GDPR) intends to strengthen and unify data protection for all individuals within the European Union [German: Datenschutz-Grundverordnung]. It was ratified in early 2016. The final enforcement is May 2018 — at which time those organizations in non-compliance will face heavy fines if they are doing business within the EU.

The GDPR definitions have direct impact to a privacy preserving architecture in terms of how to handle storage, access and user control of personal data. In the context of the GDPR personal is described as “any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person.”

GDPR sees IP-addresses, location data, pseudonyms etc. as personal data and as such these data have to be handled and protected.

It states clearly that the collection of personal data need a clear purpose and it should be reasonable when and how the consent was given. There should be always be a way for the user to give consent to use data anonymously or non-anonymously as well as to revoke the given consent.

Furthermore, it formulates the so-called “right to be forgotten”:‘The data subject shall have the right to obtain from the controller the erasure of personal data concerning him or her without undue delay and the controller shall have the obligation to erase personal data without undue delay’. Consequently, the GDPR requires service provider to erase data on demand or if they are no longer needed for fulfilling the service.

To enable anonymity of a subject, there always has to be an appropriate set of subjects with potentially the same attributes. Furthermore, there may be a need to refer to a subject without sharing its identity using pseudonyms to further increase anonymity.

Another issue is to ensure that **two** or more items of interest (IOIs, e.g., subjects, messages, actions) from an attacker’s perspective cannot linked to each other.

This should allow an OUP to provide sender anonymity. The receiver just sees the current consumption and can aggregate over time data for statistical purpose. When an outside attacker observes the communication, he can gain some knowledge even if the messages are encrypted without identifying who they are.

Accessing data from resource such as IoT devices or sensors require proper authorization. Today, this will be handled by the related management system in charge. In the future, assuming more and more unmanaged IoT devices, the OUP shall provide proper access control. When a user device or service A wants to access the resources owned by user B he or she needs an authorization in combination with a set of entitlements. In the OUP, this feature can be implemented by an authorization server.

In an OUP, there might be various data management components for storing information of different types, different domains, or different urban infrastructures. The access to this data should be protected and the access should be controlled with access control mechanisms provided by an authorization server, as well.

7.4 Smart Data and Service Provisioning

According to the reference system architecture, raw data will be processed (stored, analyzed, interpreted and linked) to create smart data. To create added value the smart data must be leveraged by smart services.

As we are expecting a growing number of smart services using an OUP, there should be the ability to support smart service deployment within the OUP. While many smart services will be also built as extensions of existing management systems, these lightweight smart services will rather follow an App-based approach using the OUP as a smart data source. One could envision that existing App-Stores will fulfill the need to deploy APPs and thus these could connect to the deployed smart services of the OUP.

Special emphasis should be given to the smart data provisioning for other urban management systems and OUPs, as this will allow for an ecosystem and thus the foundation of the envisioned data and service marketplace. Therefore, an OUP shall provide the ability to trade the respected smart data between partners. Thus, the data provisioning for such B2B relations should be supported by an OUP providing related commercial and technical standards such as Linked USDL to capture commercial conditions such as service agreements and pricing.

To support both scenarios, the smart data shall be consumable by smart services which are deployed within the platform and by external smart services which might further enrich the data. Those external smart services are connected to other OUPs or management systems which can receive the smart data from the OUP by using its Open APIs and services. The data provision must support open transport protocols such as HTTPS and secured WebSocket and open data formats such as JSON and XML.

Annex A
(normative)

Capabilities per category

For each category a set of capabilities has been identified. Their description can be found in the following table. To identify a specific capability it shall comply to the description in the table A.1. However, an OUP shall not contain all capabilities in this list and may also find additional capabilities necessary.

This table A.1 complies with the requirements of the European commission call specifications of the H2020 program. Figure A.1 provides a graphic view.

Cate-gory	No.	Capability	Description
0	0.1	Sensoring & Measuring	Senses changes in consumption or production of a commodity, instrumentation and environmental factors and records these as instantaneous values
	0.2	Data Capturing and Recording	Storing of the values, measured by the sensors in the device, in registers and other non-volatile memory structures
	0.3	Event Generation and Recording	Sensed changes are directly captured as event data or values/data are translated to events based on rules (e.g. thresholds)
	0.4	Remote Accessibility	Communication channels are opened, maintained and closed, over various communication media, to devices which are remote from the current device either on the communications network or on the HAN
	0.5	Local Accessibility	Access is provided locally to data stored on the device either via the local display on the device or through local serial or optical ports on the device which allow a local communications session to be established
	0.6	Local Integration	Describes how other devices (In-Home Devices, sub-meters, Home Management Systems, Controllable Devices etc.) are updated, read, controlled, upgraded etc.
	0.7	Customer Messaging	Describes how text, tariff, price and control messages are delivered by the device to other devices within the home or displayed locally on the device
	0.8	Local Control	An actuator (controller) is able to change things in the environment, e.g. connect/disconnect power on the connection, load limit at a connection, control smart devices within the home and its direct environment etc.
	0.9	Device Configuration	Capabilities required to maintain the device in a desired state (firmware upgrade, re-configuration, clock synchronization etc.)

Cate-gory	No.	Capability	Description
	0.10	Security Support	Local device capabilities required to support implementation of a secure end-to-end infrastructure — the physical device shall provide security services which are used to implement secure communications with other devices and secure local storage of data
	0.11	Time Keeping	Device capabilities required to ensure that accurate local time is maintained (critical for time-stamping of events and data)
1	1.1	Network Node Asset Management	Management of the full life cycle of card/chip where communications technology is deployed in the device. This includes the logistic support of knowing the device mapping with the card/chip. provisioning of the card/chip, switching the state of the card/chip and maintain its profile throughout its life in the device
	1.2	Telecommunications Network Node Configuration	The design and configuration of the structure of a telecommunication network so that data can be exchanged between the local communication network and the industry's communication network. It includes the ability to optimize the design over time when the network is in operation to meet the necessary performance and resilience targets
	1.3	Local Network Management	The network control, operation and monitoring of devices in the customer home or other related premises so that these devices can communicate securely with one another locally within the premises. Typically, this will involve a common communication protocols at physical, network and application layers operating in specialized communication devices such as communication hub, bridging device, gateway, repeaters as well as the devices
	1.4	Telecommunications Network Management	The provisioning of connectivity between the devices and the industry's terminal systems. The capability will allow telecommunication network to be monitored in flight, ensure desired network performance is achieved and that all incidents are handled in a timely manner. It will also include scheduling of messaging in view of priority by message type
	1.5	Network Security	The network will be secured at transport protocol level and at the operation of the network administration level to ensure that connectivity is maintained securely at all time
	1.6	Data Communication Management	Enables a (two-way) data communication between applications and devices via data communications protocols
	1.7	Device Provisioning	Provisioning of the device while active on the network
	1.8	Device Connection Management	Connecting devices to the network
	1.9	Device and Event Data (Edge) Processing	Collect data from devices, time-synchronize data between sensors/devices, transfer data to data management layer and/or (pre-process) data at or near device (also known as 'edge' processing), e.g. to filter, aggregate or identify (simple) events locally, before transfer.

Category	No.	Capability	Description
	1.10	Device Data and Event Storage and Distribution	Temporarily storing (raw) device and event data pre and post processing (staging area before synchronization with upper layer)
	1.11	Configuration Synchronization	Getting the needed master data for the device Integration from the upper layer(s) and possibly from the lower layer(s), including the infrastructure itself
	1.12	Message and Command Synchronization	Accepting and forwarding the command from the upper layers, managing the command status including queuing
	1.13	Data Communication, Protection & Security	Secures the data communication over the network (e.g. via encryption)
	1.14	Positioning Synchronization	Active synchronization of the position of a certain device and the manner it can be communicated with
2	2.1	Device Registration and Configuration	Registration of the static properties of the assets in the device Infrastructure and the ability to properly configure them for usage
	2.2	Operational Status Monitoring	Registration of the dynamic properties of the assets in the device Infrastructure
	2.3	Error & Alarms Diagnostics	Handling error messages, incidents, complaints and outage related cases
	2.4	Device Service Level Management & Reporting	Monitoring and reporting on device related service levels
	2.5	Device Data Unification & Validation	Unification and validation of data from single or multiple sensors from one or multiple devices , or ‘sensor fusion’, before further data processing in upper layers. This includes validation, uncertainty reduction and (re)calibration of sensor readings and actuator precision and accuracy.
	2.6	Message & Command Handling	Defining and monitoring the messages and commands, including command like connect/disconnect, power limiting/modulation, dynamic tariff/ToU programming and other control events
3	3.1	Data Ingestion	Retrieve/receive and transfer data from data sources for further processing, possibly with intermediate data storage or staging. Data sources may be highly diverse in terms of locations, formats, interfaces, protocols, standards etc.
	3.2	Data Virtualization	Making data available for data processing in a system, without the need of actually storing that data in the same system. Rather, the data is stored in another system that is enabled for virtual data access.

Cate-gory	No.	Capability	Description
	3.3	Non-time series Data Integration & Transformation	Integrate and — if needed — transform and harmonize data from one or more non-time series data sources (e.g. administrative/transactional, document, image, video, social media, geographical, master & reference data). Often in batches with e.g. daily frequency.
	3.4	Time-series Data Integration& Transformation	Integrate and –if needed- transform, harmonize and time-synchronize data from one or more time series data sources or ‘streaming data sources’, typically device, sensor and (raw) event data about infrastructure, weather, traffic etc. Often continuous, in (near) real-time.
	3.5.	Data Fusion	Using (time-series or non-time series) data integration to combine data from different data sources, representing the same object or actor, thus enabling more complete views and insights.
	3.6	Data Aggregation	Summarizing data by grouping data entities in higher order categories, and/or by calculating sums, averages, maximal value, minimal value, or other numerical aggregates.
	3.7	(Complex) Event Processing	Filtering, matching, analyzing of (real-time, time-series) data, in order to identify events. Events may be simple or complex (in the sense that underlying data may be from multiple locations and/or may apply to longer time intervals, or that events are derived from other events). Identified events are stored and published for further processing and action.
	3.8	Data Logistics	Data storage on and data retrieval from (digital) media in one or multiple (distributed) systems, back-up/restore, life cycle management and archiving, physical transfer of data between systems through communication networks.
	3.9	Data Privacy Protection	Protecting privacy of citizens (and other stakeholders) by preventing unethical, unlawful, unregulatory, unauthorized or unwanted access to and use of data, both by government, NGO, commercial or other organizations and individuals. This involves policies, processes, people and technology like encryption, anonymization, pseudonymization and data usage monitoring. Refer to EU Data Protection Act and other relevant EU member state or local legislation for full coverage of requirements for this capability.
	3.10	Data Security Management	Managing confidentiality, integrity and availability of data, by means of security policies, processes, people and technologies for user authentication, authorization (functional and data perspective), security zoning, intruder detection etc.: see also security related in the ‘common services capabilities’ layer.
	3.11	Data Assurance Management	Monitor, validate and — if needed and possible — improve data quality, in aspects like completeness, validity, consistency, timeliness, accuracy, compliance (with respect to regulations or standards), during data recording/entry and/or during further data processing.

Cate-gory	No.	Capability	Description
	3.12	Data Modelling	Structuring of data in terms of identifying data entities or classes, their attributes or properties and relationships or associations between them. Often in representing logical or technical data structures in entity-relation or object oriented class diagrams.
	3.13	Data Discovery	Discovering the existence of certain data or datasets and/or exploring data in order to understand data structures and characteristics, e.g. like certain patterns to identify correlations or to make predictions. Exploration may be visually for human processing and/or automated by applying machine learning/data mining algorithms.
	3.14	(Open) Data Publication	Making data available to “data consumers” to either a restricted set of actors (people or systems) or open to any actor. Data publication may occur in several data formats (preferably standards based), in real-time or batch oriented, and through several communication channels and protocols.
	3.15	Metadata Management	Managing “data about data”, including data semantics (meaning, definitions, concepts and relations), data ownership, data privacy and data confidentiality classification, data quality indicators, data lineage (origin of data and how data is derived from other data), data usage statistics, and so on.
	3.16	Master and Reference Data Management	Managing “slowly changing”, non-transactional and non-time series data, typically about actors and objects and their core attributes. Reference data is mostly data to categorize, group or aggregate other data. Typically master and reference data are used in many systems and contexts, and should preferably be kept consistent and synchronized.
	3.17	Analytics	The process of analyzing data for descriptive (what happens), predictive (what will happen) or prescriptive (what is best to happen) purposes. May involve visualization, statistical, geospatial, machine learning and other techniques.
	3.18	Reporting and Dashboarding	Publishing the results of (descriptive) analytics, often based on (key) performance indicators with their actual, predicted, benchmarked, planned/budgeted or expected measures, and contextualized with location, time, group or other category data. Possibly formally validated or certified by (3rd party) audit/control functions.
	3.19	(Geo)Visualization	Visualizing data or (analytics) insights derived from data, in graphical, info graphical, geographical or other formats on small (mobile) to very large (public communication) 2D-screens, or in 3D virtual or augmented reality. Preferably in a dynamical way with actor interaction support (zoom, pan, filter, layering, …).
	3.20	Semi-/Unstructured Data Management	Additional data management capabilities that are specific to semi-structured or unstructured data, like text, sound, images, videos or other. This may include the use of unstructured data analysis (e.g. text mining) that may be applied for automated metadata classification or other purposes.

Cate-gory	No.	Capability	Description
	3.21	Integral Search & Navigation	Enhancing the findability and accessibility of both structured and unstructured data by offering the possibility of searching (by keywords) and/or navigating (by browsing through categories), preferably across different data sources from possibly multiple urban actors and organizations.
	3.22	Data Recording	Facilitating “systems of engagement” like mobile apps or web sites to record data in a safe, secure and privacy abiding way, that was created by their users/visitors. This facilitates an easier and more speedily innovation processes for new (lightweight, start-up created) urban applications, that otherwise would require their own “data recording back-site”. This also includes “data write back” services for intelligence or analytical applications, for instance to record data about what if scenarios, budgets or prognosis.
4	4.1	Data Exchange	Exchanging data between systems, typically from multiple public and private organizations, in a certain (standard) format, using one or more protocols. May require transformation of data between sender and receiver.
	4.2	Messaging	The process of communication between systems by sending and receiving messages, representing requests or responses that can be processed automatically. This includes message queuing, brokering, and publish/subscribe services.
	4.3	Load Balancing	Distribute the “load” on required resources for processing in an evenly manner, based on the actual availability of (system) resources, assuming that there are alternatives to choose from.
	4.4	(Open) API Management	Management of application program interfaces (APIs), including registration, publication, usage policies, access control, usage statistics. APIs provide automated access from one system to functionality or data in other systems. Such access may be restricted to e.g. internal actors or open to broader groups of actors.
	4.5	Rules Management	Managing rules for automated processing, that represent business logic. Such rules may be about validation of data entry, process order and exceptions, authorization policies or other “logic”.
	4.6	Event Management	Manage events that were identified by (complex) event processing (see category 3) or events from other sources, like events derived from administrative transactions, triggered by (business) rules or events received from external sources. Any such events may require the invocation of a process to deal with the event, an alert sent to human beings or systems, or other responses.
	4.7	Transaction Management	Managing transactions within and between organizations according to applicable legislation, contracts and/or other rules. Typically this requires the consistent and complete recording of transactions in one or more systems, maintaining synchronicity and consistency between multiple systems or ledgers and associated balances and aggregates.

Category	No.	Capability	Description
	4.8	Process, Choreography, Orchestration and Monitoring	Automated monitoring and execution of (business) processes, based on process flow models and rules. Often involving interaction with multiple actors (systems and/or people).
	4.9	(API) Service Management	Managing services (e.g. APIs, open data publications, data exchanges, transaction management support or other more higher level services) by keeping a service “catalog”, service provisioning, service life cycle management (versioning, upgrades, termination), service contract management and monitoring, service subscription management, and so on.
	4.10	Publish, Subscription and Notification Management	Based on events or publications by private or public urban actors, other human or system actors may receive notifications of the occurrence of such events or publications, possibly depending on certain criteria or rules, and through a diversity of communication channels (messaging, events, e-mail, SMS, etc).
	4.11	Collaboration, Communication and (Social) Media	Provisioning of (digital) facilities and services for the purpose of collaboration between private and public actors, including explicitly facilities for citizen participation. These facilities may range from communication through several, including social media to (digital) spaces that allow actors from different organizations and groups to work closely together, possibly in the context of SCC projects.
	4.12	Personalization	Offering of services (including data, functionality, and HCI configurations) that are targeted and tailored toward individual or groups of actors, explicitly respecting all privacy, security and other relevant legislation, policies and rules.
	4.13	Ecosystem Market Place	Platform and processes to facilitate the publication of apps/applications, (open) datasets or other services by private or public urban actors, and their usage/consumption, including contracting, licensing, authorization, transaction processing etc. May also include some form of quality monitoring and/or promotion, by applying standards, design criteria/guidelines etc.
5	5.1	Business Models, Procurement & Funding	Integrating local solutions in an EU and global market. Create new “business models” and promote successful “business models”, especially those in line with the general policies and goals of a particular city or community, leveraging the opportunities in improved communication, collaboration and coordination, offered by SCC projects and processes and the supporting open urban platform. These opportunities may include e.g. joint procurement and funding, or knowledge sharing thereof.

Category	No.	Capability	Description
	5.2	Standards	Providing the framework for consistency, commonality and repeatability, without stifling innovation. Reduce friction and improve speed and accuracy in communication and collaboration between both humans and systems. This entails active promotion of the use of standards (global, EU, national or sectoral) or coordination of standardization efforts across sectors, organizations, departments and other actors in the city and community ecosystem.
	5.3	Open Data	Understand the growing pools of data; making it accessible — yet respecting privacy. Support and operationalize collaboration, transparency and create cross-fertilization innovation opportunities between city and community actors by publication of own data as open data, using open data from others. Open data is preferably formatted and defined by applying relevant standards, including standards for linked data/semantic web. Use feedback from open data publications for data quality improvement. Facilitate and propel innovation, based on open data, e.g. by organizing open data application contests or hackathons'.
	5.4	Metrics & Indicators (Performance Management)	Enabling cities to demonstrate performance gains in a comparable manner, based on well defined (benchmark) metrics and indicators. Typically these include EU climate goals related metrics and indicators, like CO_2 footprint.
	5.5	Knowledge Sharing	Accelerate the quality of sharing of experience to build capacity to innovate and deliver. Supporting knowledge sharing in e.g. projects for innovation or shared delivery operations, between actors and organizations in a city's ecosystem, both public and private, both citizens and experts or other knowledge "producers" or "consumers". This entails (social) facilitation of knowledge sharing between people, pro-active and adaptive communication, and information sharing, both ad hoc and in structural and automated ways.
	5.6	Integrated Planning	Work across sector and administrative boundaries, and manage temporal goals. Optimization of processes to e.g. reduce costs, social impact or environmental impact, by improving planning or (and scheduling) across (administrative) disciplines and sectors that are involved in city/community activities. May range from long term planning, based on integrated predictions (e.g. better coordination of district building, utility infrastructure, public transportation and roadwork construction) to operational scheduling and real-time situational awareness (e.g. quicken dispatch of emergency services by dynamic traffic management/traffic light adaptation).

Cate-gory	No.	Capability	Description
	5.7	Policy & Regulation Management	Create the enabling environment to accelerate improvement. E.g. by reducing administrative burdens for innovation, or by improving integral accessibility, by reducing the number or by removing inconsistencies between rules and regulations from different policy perspectives (building, environment, safety, etc.). Another example here is the automated exposure (through API management) of applicable rules and regulations, to be used by commercial parties like e.g. car sharing or house/room sharing platform providers, that possibly operate in multiple countries and/or cities, and have to deal with multiple rules that may differ per city or district.
6	6.1	Sustainable Urban Mobility — Charge point management — Tariff management — Location management — Settlement — Etc.	Improving both urban mobility and sustainability. This may entail cross-modal planning (air, road, rail, water) of infrastructure and transportation capacity and operational optimization of actual transport of people and goods. It is also about innovations like e.g. electric transportation and car sharing.
	6.2	Sustainable Districts & Built Environment — Planning — Design — Transactive Energy Management — Etc	The built environment can become more sustainable in many ways. These include smart homes and smart buildings for energy usage and emission reduction.
	6.3	Integrated Infrastructure & Processes — Intelligent Lighting Management — Multi modal Transportation Management — City Information Management — Etc.	Improving efficiency, effectiveness, safety and reducing social, environmental or other impact of the installation, inspection, maintenance, removal and operations of infrastructure and city/community assets in general, across sectors and domains (e.g. water, energy, gas, public transportation, road traffic, etc.). E.g. by coordinated planning (location and time) of activities in order to reduce impact of activities, by combining condition data to optimize failure prediction, or other cross-sector cross-asset optimizations.
7	7.1	Strategic Stakeholder Engagement	The ability to engage with relevant stakeholders to specifically define the legitimacy, influence and urgency of stakeholders, to prioritize the various interests, and to jointly define the roadmap and intended system outcomes.
	7.2	User Experience Management	Design of the way user navigate through an application, including ergonomics of how information is presented and visualized to humans on any device.

Cate-gory	No.	Capability	Description
	7.3	Citizen Focus	Include citizens into the process as an integral actor for transformation. This entails several aspects, including personalized omni-channel interaction, with multiple city departments and other organizations. Cities may keep track of preferences, profiles and other not-only-administrative characteristics of citizens and other actors in 'urban actor management', provided that the privacy and possible sharing of actor-specific data is in full control of data owners; each and every individual actor, and of course is in compliance with privacy laws and regulations. Actors should be able to have control in which specific public or private organizations may have access to their personal or profile data, balancing their privacy with other personal goals (e.g. economic benefits that may arise if someone decides to share data with commercial parties).
	7.4	Public - Private Collaboration	The ability to define and encourage the development of public-private partnerships that can support specific of generic initiatives within the scope of the Urban Platform. The ability to manage the co-operative arrangements between one or more public and private partners, typically of a long term nature.
	7.5	Strategic Goals Management	The ability to define long, mid and short term goals for achieving smart cities and societies via the deployment of an open urban platform, including metrics and a process that helps a city move toward its stated goals by keeping existing initiatives satisfied, and recruiting new initiatives necessary, in a responsible and ethical way.
8	8.1	Security Governance	The capability of establishing and maintaining a framework and supporting management structure and processes to provide assurance that information security strategies are aligned with and support business objectives, are consistent with applicable laws and regulations through adherence to policies and internal controls, and provide assignment of responsibility, all in an effort to manage risk.
	8.2	Access Control	The capability to manage general system access control that includes authorization, authentication, access approval and audit.
	8.3	Privacy & Security Risk Management	The capability to identify, assess and prioritize privacy & security related risks, followed by a coordinated and economical application of resources to minimize, monitor and control the probability and/or impact of unforeseen events.
	8.4	Auditing	The capability to monitor and record selected operational actions from both application and administrative users. You can audit various kinds of actions related to data access and updates, configuration changes, administrative actions, code execution, and changes to access control. You can audit both successful and failed activities.

Cate-gory	No.	Capability	Description
	8.5	Cryptography	The capability to have an indispensable measure for protecting information in computer systems. Cryptography is a method of storing and transmitting data in a particular form so that only those for whom it is intended can read and process it.
9	9.1	Operations Center	Facilities for integral monitoring and/or control of processes and their associated actors and objects, bringing together many other capabilities (including data fusion, (complex) event processing, analytics, visualizations, collaboration, communication & (social) media and process orchestration & monitoring) for a broad variety of applications.
	9.2	Service Management	The capability of performing a set of activities — directed by policies, organized and structured in processes and supporting procedures — that are performed by an organization to plan, design, deliver, operate and control information technology (IT) services offered to customers.
	9.2	Service Management	The capability of performing a set of activities — directed by policies, organized and structured in processes and supporting procedures — that are performed by an organization to plan, design, deliver, operate and control information technology (IT) services offered to customers.
	9.3	Channel Management	The capability to perform various techniques and strategies to reach the widest possible customer base with the effective use of contact channels. The channels are nothing but ways or outlets to market and sell products. The ultimate aim is to develop a better relationship between the customer and the product or service.
	9.4	Human Computer Interaction	Defines the way humans interact with different devices in different places, times and contexts.
	9.5	Market Interaction	The capability of interacting with the market in a more or less standardized manner based on open standards.
	9.6	Third-Party Interaction	The capability of interacting with partners in an ecosystem in a more or less standardized manner based on open standards.

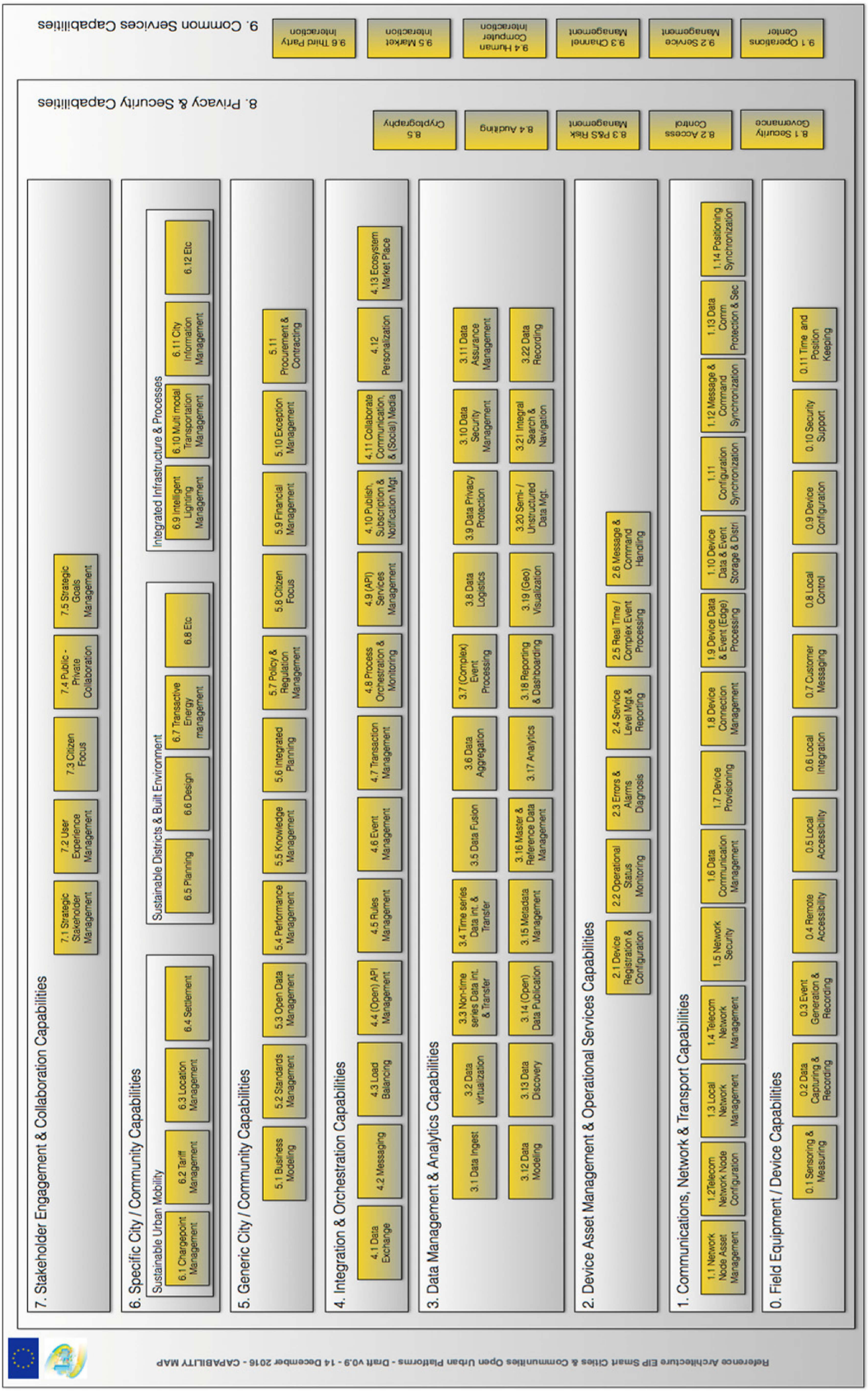

Figure A.1 — EIP SCC Urban Platform Capability Map with capabilities per category

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