IRIS

Integrated and Replicable Solutions for Co-Creation in Sustainable Cities

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# Deliverable 4.2

## Functional & technical requirements for integrated, interoperable and open solutions, standards and new business models

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# Executive Summary

The City Innovation Platform (CIP) plays a crucial role in the IRIS-project to collect, manage and exchange data for the development of new applications and services. The CIP and its components will manage large volumes of data and information coming from domain specific solutions, like waste collection, parking, air quality or energy consumption, from municipal systems, external platforms and other data sources. To achieve a standards-based, shared and reusable CIP, across the participating cities, we need a common reference architecture.

This document describes the Reference Architecture for the City Innovation Platform (CIP). It builds upon previous documents about Open Urban Platform Reference Architectures and the D4.1 (Report with analysis of current baseline Lighthouse ICT systems). The document specifies the stakeholders, capabilities and components of CIP in more detail.

The CIP Reference Architecture provides:

- a common language for all the stakeholders
- consistency of functional and technical requirements for the implementation of the CIP
- guidance to validate solutions against the reference architecture
- support for common standards, specifications and patterns
- support the requirements and enable the capabilities associated with Business Models defined in IRIS

To establish broad support for the City Innovation Platform, it has to facilitate the demands and requirements of different stakeholders. Based on their demands the capabilities of the CIP are described, following the methodology of the EIP-SCC Open Urban Platform standard. The capabilities are compared and matched (where possible/applicable) with the CIP-components identified and described in the original IRIS-proposal.

After elaborating on the stakeholders, capabilities of existing open urban platforms and discussing the five CIP components in relation to the most relevant capabilities, this document describes “Design Principles” for CIP. These principles provide guidance for the implementation of functional and technical solutions in CIP.

The CIP is the connection between a wide range of stakeholders, solutions and services, which will all demand appropriate governance, access and responsibilities. Therefore, CIP allows different strategic, technological and infrastructural scenarios for the actual implementation, and thus different platform business models. The Reference Architecture facilitates these different scenario’s by offering a modular and federative approach. To operate and maintain a City Innovation Platform in such a heterogenous environment, cities should be clear about the underlying business models for an Open Urban Platform. There are different options (§ 7.1.2), each with its own specific characteristics, challenges and stakeholder roles. Although this document provides generic Design Principles, the actual implementation of the Reference Architecture depends on the technical, organizational and infrastructural choices made.

With regard to the energy-related challenges within the IRIS-project in particular and smart city topics in general, the City Innovation Platform will operate within a federation of other platforms, from multiple vendors, connecting different stakeholders and interworking between cities. As such, the City Innovation Platform Reference Architecture will pursue the design and development of a federative, distributed and decentralized infrastructure ("System of systems") each serving a community of data and service providers. To realise this potential, following open standards is of key importance.

Based on the development of the CIP Reference Architecture, the following Design Principles can be added to the existing work on development of Open Urban Platform Reference Architectures:

1. Reuse existing, proven reference architectures and adapt them to support the IRIS-goals ;
2. Develop a layered architectural approach that is technological, implementation and market structure agnostic (no vendor lock in);
3. Aim for decoupled and distributed components to support adaption to future developments and to support different business models
4. Enforce interoperability and openness, but ensure legacy compatibility
5. Focus on delivering smart services for users based on Open API´s and provide easy to use documentation, examples and quality data
6. Enable a federated, scalable approach, to connect various urban platforms
7. Develop a Marketplace to create an ecosystem of data-providers and -users and support monetization of data-solutions.
8. Make capabilities the central elements to ensure a common ground
9. Implement privacy and security by design principles

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## List of Terms and definitions

| Abbreviation | Definition |
|---|---|
| API | Application Programming Interface. A software intermediary that allows for distinct applications or systems to interact with one another. |
| Capability | The abstract representation of what is needed to produce an outcome along with goals and metrics for that outcome. |
| CIM | City Information Model |
| CIP | City Innovation Platform |
| CIP-component | The following five components of the City Innovation Platform:<br>1. Data management framework<br>2. Data market<br>3. Security and privacy<br>4. Platform management<br>5. Proprietary systems connectivity (federated solution) |
| CKAN | Comprehensive Kerbal Archive Network. Open source catalogue system for open data portals. |
| Data Portal | A software solution (usually a website) that presents a catalogue of searchable and downloadable datasets in a user-friendly and uniform way. |
| Data Set | A collection of data that can be downloaded and processed further. |
| DCAT-AP | Data Catalogue Vocabulary (-Application Profile), is an RDF vocabulary designed to facilitate interoperability between data catalogues published on the web. The Application Profile is developed by the European Commission for interoperability optimisation between European Data Portals |
| DPA | Data Protection Authority |
| DPO | Data Protection Office |
| EIP-SSC | European Innovation Partnership on Smart Cities and Communities |
| ESPRESSO | EU-project (2016-2017) that identified a collection of open standards for smart cities that work well together ("conceptual standards framework") and have been proven |
| FIWARE | "Future Internet-ware"; an open software- and standards framework |
| Functional requirement | Functional requirements describe the desired end function of a system to assure the design is adequate and meets user expectations. In this document also used as "Design Principles". |
| GDPR | General Data Protection Regulation |
| IAM | Identity & Access Management |
| Interoperability | The ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged. |
| IoT | Internet of Things |
| Linked Data | A method of publishing structured data so that it can be interlinked and become more useful through semantic queries, facilitating the sharing of machine-readable data on the web. |

| | |
|---|---|
| Metadata | Data about data |
| Open data | Data carrying an open licence stating it can be freely used, re-used and redistributed by anyone, for any purpose. |
| Open & Agile Smart Cities | Open & Agile Smart Cities (OASC) is a global initiative connecting cities, advocating de facto standards, and sharing best practices. |
| OUP | Open Urban Platforms (also working group of EIP-SCC)<br>Definition: (BSI, 2016) |
| PbD | Privacy by Design |
| PEAR | Privacy Enhancing ARchitecture |
| PET | Privacy Enhancing Technology |
| PIA | Privacy Impact Assessment |
| PMRM | Privacy Management and Reference Model and Methodology |
| PRIPARE | Preparing Industry to Privacy-by-design by supporting its Application in Research |
| Reference Architecture | A template that offers a common language and support for standards, specifications and patterns, a list of functions and interfaces (APIs) and their interactions with each other. |
| RDF | Resource Description Framework: a standard model for data interchange on the web. |
| Role | Responsibility and/or activity of a stakeholder within the City Innovation Platform |
| SLA | Service Level Agreement |
| Stakeholder | A person or group with specific interest in the City Innovation Platform. |
| Technical requirement | Technical requirements define what is required to deliver the desired function or behaviour from a system to a user's standards. |
| TM-Forum | Is a neutral, non-profit member organization. |
| USEF | The Universal Smart Energy Framework (USEF) is an international common standard that ensures smart energy technologies and projects are connectable at lowest cost. |
| WP | Work Package |

*Table 1 Definitions*

# 1. Introduction

The City Innovation Platform (CIP) plays a crucial role in the IRIS-project to collect, manage and exchange data for the development of new applications and services. The CIP and its components will manage large volumes of data and information coming from vertical solutions, municipal systems, external platforms and different data sources. To achieve a standards-based, shared and reusable CIP, across the participating cities, we need a common reference architecture. That´s what this document is about.

For a Platform, we follow the definition TM Forum uses: "a *Platform is a business based on enabling value-creating interaction between external producers and consumers. The platform provides an open, participative infrastructure for these interactions and sets governance conditions for them. The platform's overarching purpose is to consummate matches among users and facilitate the exchange of goods, services, or social currency, thereby enabling value creation for all participants*." (Parker, 2016).

For (Open) Urban Platforms, we follow the definition as mentioned in the EIP-SCC Urban Platform Management Framework (BSI, 2016). An 'Urban Platform' is…

- … the implemented realisation of a logical architecture / design that brings together (integrates) data flows within and across city systems
- … and exploits modern technologies (IoT/sensors, cloud, mobile, analytics, social media etc)
- … 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
- … in order to transform, in a way that is tangible and measurable, outcomes at local level {e.g. increase energy efficiency, reduce traffic congestion and emissions, create (digital) innovation ecosystems, efficient city operations for administrations and services}

This document is about an Urban Platform Reference "architecture" for IRIS, meaning a template consisting of functionalities (capabilities) and their interfaces and interactions. There are a lot of ways to look at architecture and a lot has already been written on this subject. In this document we use, translate and adapt the information so that it supports the challenges in the IRIS-project. The CIP-reference architecture takes into account that "things" are changing rapidly and that it has to accommodate those changes and provide an evolutionary architecture (Neal Ford, 2017). The CIP-Reference architecture leans heavily upon the results from the EIP-SSC (working group Urban Data Platforms), the ESPRESSO project, the ongoing efforts within TM Forum (City Platform) and experiences from FIWARE and the Open Geo Consortium.

## 1.1 Scope and objectives of the deliverable

Task 4.2 of Work Package 4 is described in the IRIS project management plan as "CIP technical solution reference architecture". The deliverable of this task (D4.2) is to describe the functional and technical requirements for integrated, interoperable and open solutions, standards & new business models.

The objective of this deliverable is to provide:

- a common language for all the stakeholders
- consistency of functional and technical requirements for the implementation of the CIP
- guidance to validate IRIS integrated solutions against the reference architecture
- support for common standards, specifications and patterns

- contribute to business modelling by relating capabilities to business roles.

This CIP Reference Architecture is not a solution architecture, although existing technologies and software components are used to explain certain capabilities. In general: the CIP Reference Architecture is supposed to be technology agnostic and future proof.

This document provides information that applies to all cities and parties involved in the IRIS-project. Based on this document, specific implementations of this architecture may be developed within each city. These specific implementations, based on this Reference Architecture, are out of scope for this document and will be described in D4.4.

## 1.2 Structure of the deliverable

This deliverable describes the different stakeholders, capabilities and components of the City Innovation Platform, focusing on generic Design Principles that support the functional and technical implementation of the CIP.

First, we start with an overview of the different stakeholders related to the City Innovation Platform. Each stakeholder has demands and requirements that need to be fulfilled to make the CIP a success. Based on these demands the required platform capabilities of the CIP are described. These platform capabilities, derived from the EIP-SSC Reference Architecture, provide guidance for the five City Innovation Platform components. The platform capabilities are linked with and attributed to (where possible/applicable) these five CIP-components, as identified and described in the original IRIS-proposal.

The five identified CIP-components are:

- Datamanagement framework
- Data market
- Security and privacy
- Platform management
- Proprietary systems connectivity (federated solution)

After elaborating on the stakeholders, platform capabilities and CIP-components, this document describes the Design Principles to support functional and technical implementation of the CIP.

## 1.3 Target Audience

This document focuses mainly on users that are involved in the functional and technical development, implementation and maintenance of a City Platform (= City Innovation Platform), like architects, policy makers, developers and platform providers. They can use this document to check if their solutions will fit to the CIP Reference Architecture.

## 1.4 Relation to Other Tasks and Deliverables

The City Innovation Platform is the foundation under most of the solutions within the IRIS-project. It offers data and services for the transition tracks in WP1. It enables KPI-monitoring and facilitates the development of new business models (WP3) through the Data Market, open API´s and different data licences.

This Reference Architecture builds upon the analysis done in D4.1, where the current situation in the different Lighthouse cities regarding data and technical infrastructure is described. The main conclusion of D4.1 is that all the Lighthouse cities already have mature and closed-standard platforms to manage and share data but the development of added value data services remains limited. For their part, most private partners also have technical platforms but they are not aligned with European and / or unopened standards; technical adaptations will have to be made at this level to finally be interoperable with the CIP.

The Reference Architecture in this document describes generic Design Principles that guide the implementation of the City Innovation Platform. The focus is on functional “requirements” (“what”). In D4.4 these requirements will be worked out into a technical solution reference architecture for CIP components (“how”).

The Reference Architecture will also be useful in the development of the Data Governance Plan (D4.3).

For the demonstration projects in WP5 (Utrecht), WP6 (Nice) and WP7 (Gothenburg) the City Innovation Platform Reference Architecture offers the components to execute the projects.

# 2. Methodology

Open Urban Platforms or City Platforms such as the City Innovation Platform, follow design principles, based on Open API's to support collection and analysis of (enriched) data flows within and across city systems. Many architectures for urban or smart city platforms have already been developed and described. The first step in the development of the CIP Reference Architecture was research into these existing Open Urban Platform Reference Architectures, their characteristics, similarities and building blocks. Annex 1 describes three of these existing Reference Architectures (EIP-SCC/ESPRESSO, FIWARE, TM-Forum).

The conclusion from the research into Open Urban Platform Reference Architectures is that much work has already been done to describe urban platforms for smart cities. This document is not about a new architecture. It builds upon previous learnings and experiences. Nonetheless it is necessary to create a reference architecture for the IRIS City Innovation Platform too. The Lighthouse cities and the other parties involved in the IRIS-project need a common understanding and a shared vocabulary for the tasks at hand. To translate and adapt existing work for IRIS, and to contribute to and refine the existing work, this document focuses on three elements of the CIP Reference Architecture: the stakeholders, the capabilities and the components with open API´s.

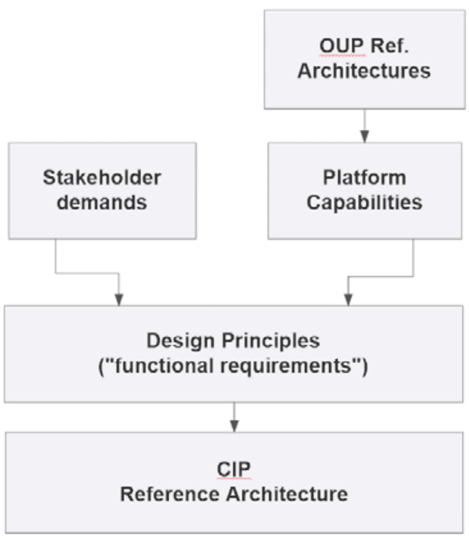


*Figure 1 Methodology for CIP Reference Architecture*

The aim of the IRIS CIP is to create a solution that facilitates the harvesting of urban data and the creation of new solutions and business models. The CIP collects, processes and stores data, acts as a logical urban infrastructure and connects to existing platform architectures. It follows principles for federation and a layered approach for decomposition of logical clusters.

The City Innovation Platform as described in the IRIS-project is shown below. It comprises three core elements: supply side (bottom, southbound interfaces), the City Innovation Platform (middle) and the demand-side (top, northbound interfaces). In the next chapters this concept will be described in more detail, starting with the demands from different stakeholders.

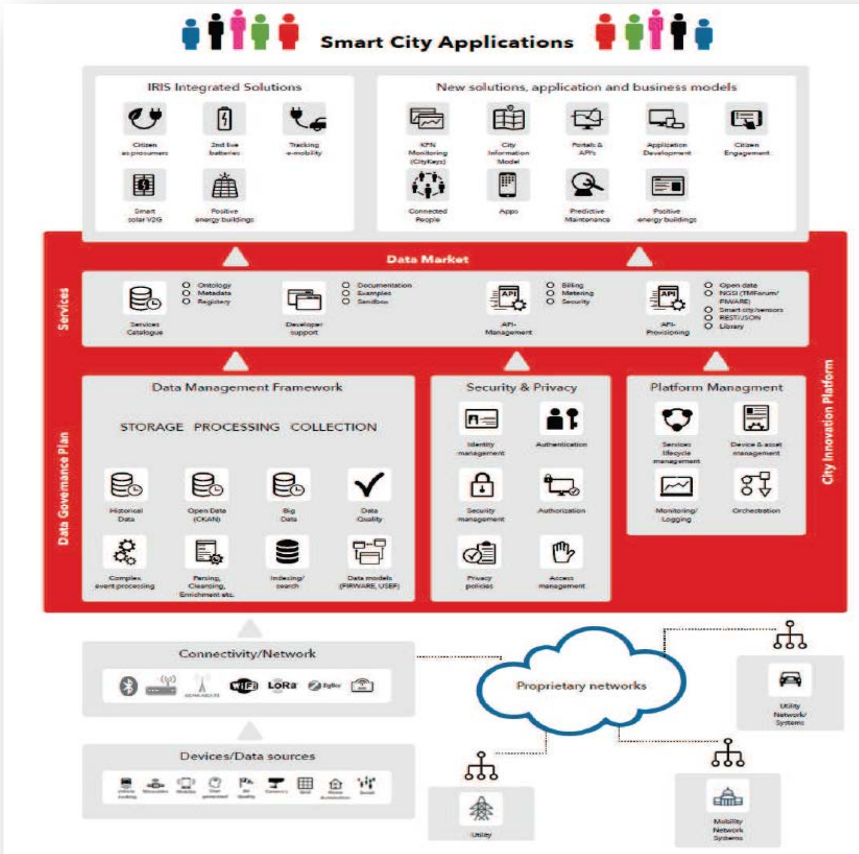


*Figure 2 IRIS City Innovation Platform overall architecture (Source: IRIS GA)*

# 3. Open urban platform capabilities

To meet the demands of stakeholders, the City Innovation Platform as an open urban platform needs to have different capabilities.

These Platform capabilities are the fulfilment of functional requirements stemming from the demands of the stakeholders mentioned in the previous chapter. Capabilities offer guidance for CIP API's, governance and business modelling. If offers also a way to make choices about the role(s) of each stakeholder in the CIP. For example, based on stakeholder demands and available roles, a city can decide that they want to be Data Platform Owner, while another city can decide that they are a Data Owner and want a governance structure and rules on how their data can be used by others.

Capabilities are grouped and structured in a Capability Map. The Capability Map is a tool for planning and assessment of capabilities that are already in place, need further development or are lacking, in order to meet the functional requirements of stakeholders.

Within the EIP-SSC Open Urban Platform reference architecture a capability map has already been developed (which was used for the ESPRESSO-project, and has been adopted by the German Institute for Standardization (DIN, 2017)). The EIP-SCC OUP capabilities are mentioned in detail in Annex 2. TM Forum is also working on the definition of capabilities for a City Platform. These capabilities are mentioned in Annex 3. In the next paragraph the EIP-SCC/ESPRESSO and TM Forum capabilities are described in short, before they will be matched with the City Innovation Platform components in Chapter 5.

## 3.1 Open Urban Platform Capabilities: EIP-SSC

In the Open Urban Platform reference architecture based on the works of EIP-SSC and ESPRESSO, ten categories of capabilities are identified (see figure 4).

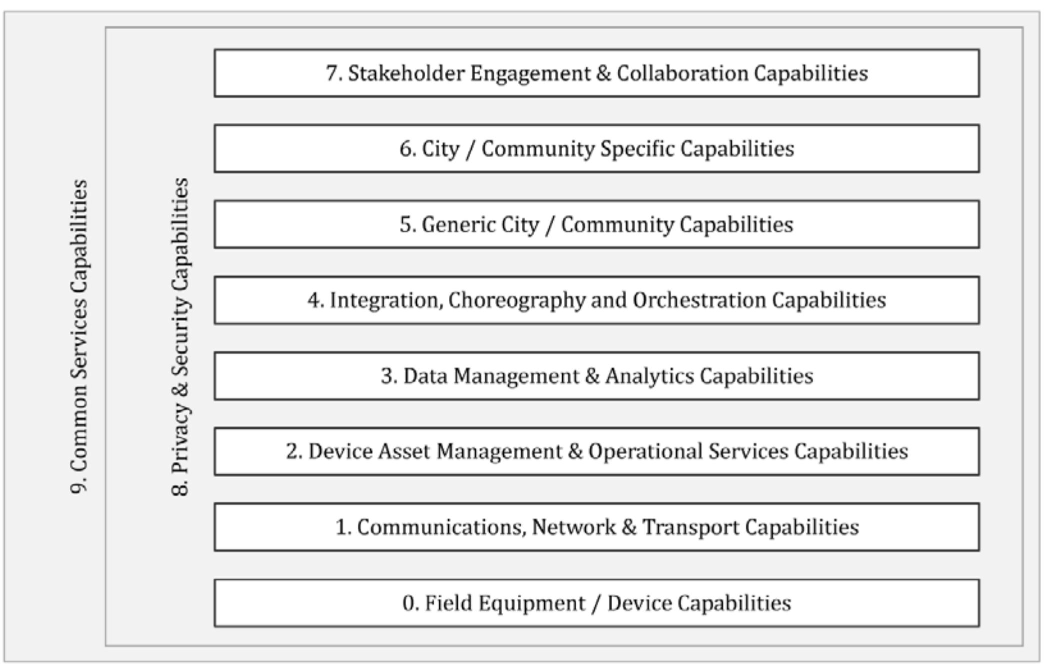


*Figure 3 EIP SSC Urban Platform Capability Map: 10 categories*

These ten categories of capabilities are described in more detail in the below table.

| 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 analyse, 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. |

*Table 2 Description of capabilities*

Each of these ten categories of capabilities contain a number of individual capabilities. The scheme below shows this in an overview. Annex 2 provides a detailed description of all capabilities in the ten categories.

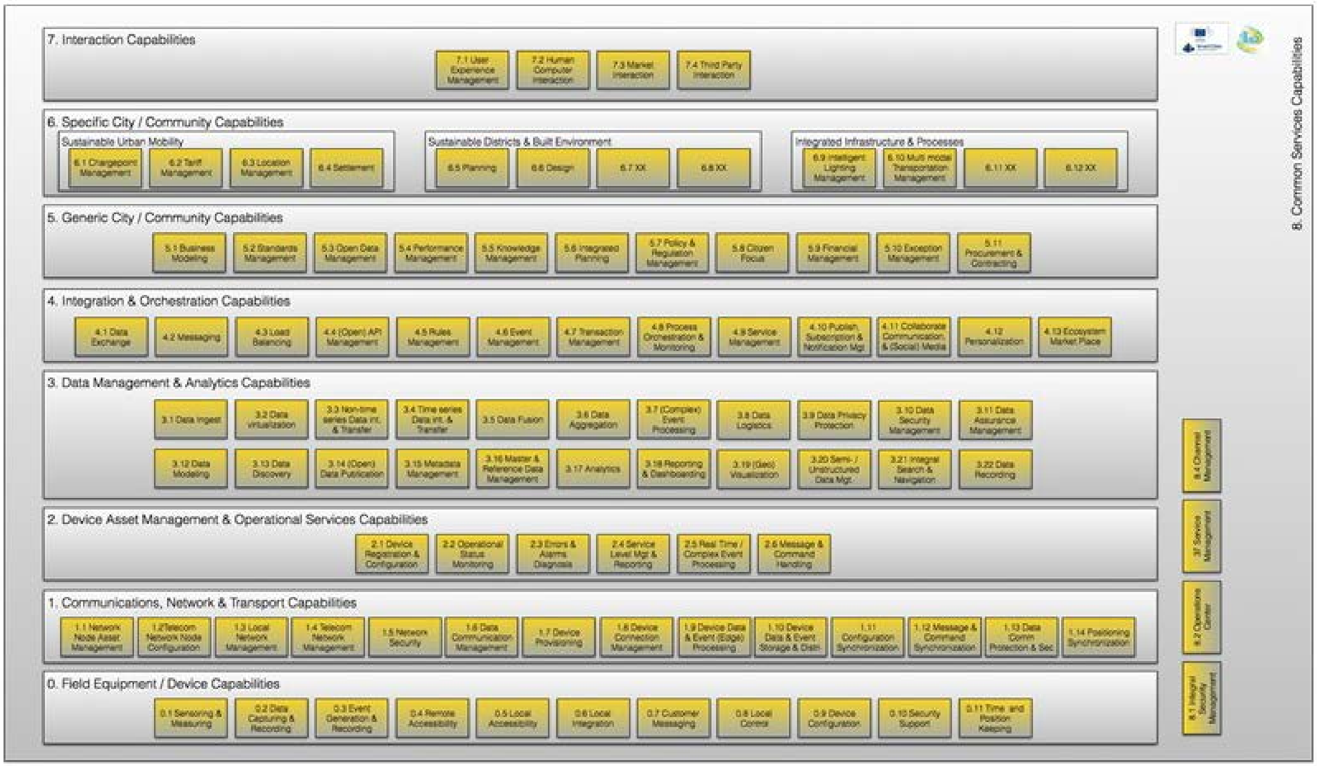


*Figure 4 EIP SCC Urban Platform Capability Map with capabilities per category*

The core services of an Open Urban Platform are about connectivity, integration, processing and interfaces and relate to capability category 2 (Device Asset Management & Operational Services Capabilities), 3 (Data Management & Analytics Capabilities), 4 (Integration & Orchestration Capabilities) and 5 (Generic City / Community Capabilities) of the capability map in figure 6. In Figure 7 these core services are plotted on the capability categories, to indicate the focus of the City Innovation Platform.

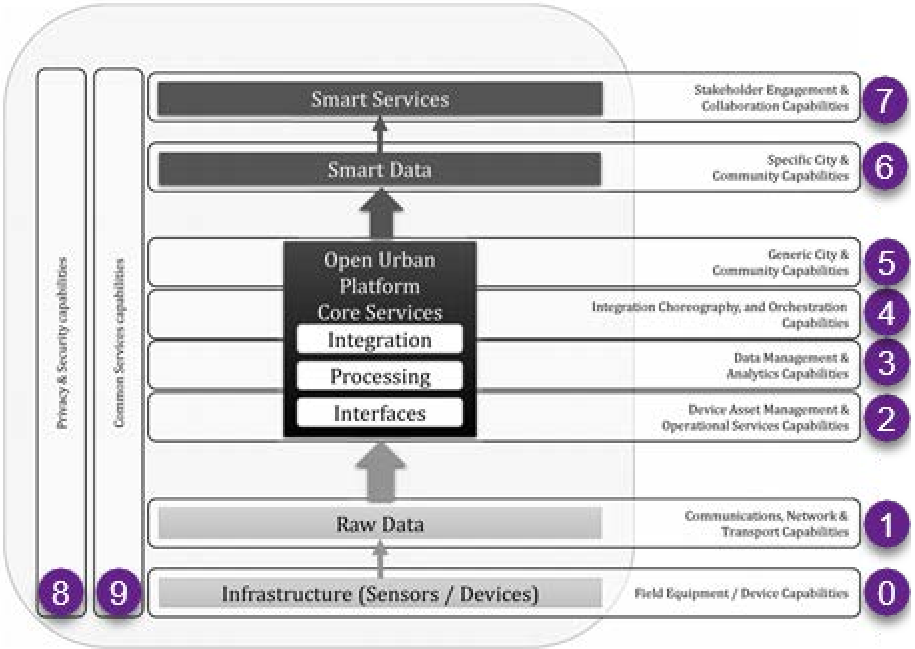


*Figure 5 Open Urban Platform capability categories connected to CIP functions*

## 3.2 City Platform Capabilities: TM Forum

TM Forum is also working on describing supporting capabilities City Platforms (TM Forum, 2017). TM Forum defines thirteen categories, as shown in figure 8.

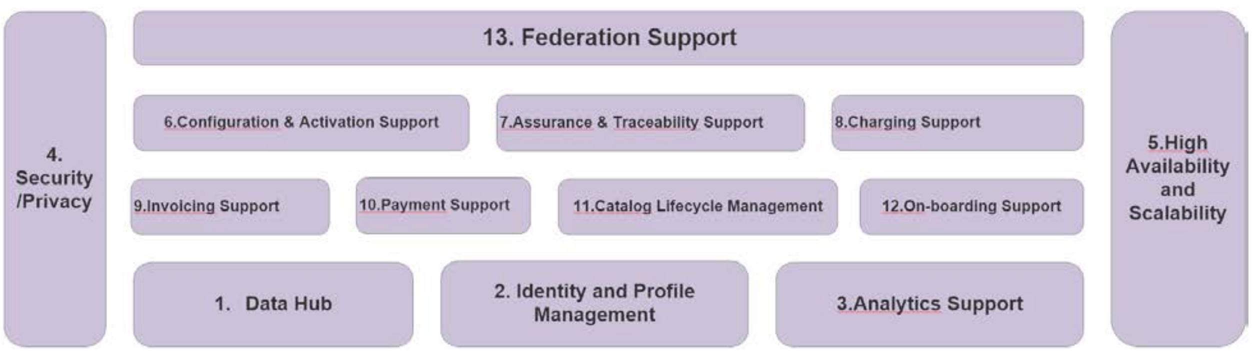


*Figure 6 13 Supporting capabilities from TM Forum City as a Platform Architecture*

In their work TM Forum attributes these supporting capabilities to different stakeholders/roles (see Annex 3).

This setup offers helpful assistance for the development of a data governance plan with clear responsibilities for each stakeholder. It also provides help to define supporting functions, like service level management, asset management and compliance with privacy and security regulations. The figure below shows one category (Data Hub) with the categories TM Forum describes for this category. In comparison with the capabilities from EIP-SSC, TM Forum puts more emphasis on supportive business capabilities. In that sense EIP-SSC and TM Forum are complementary.

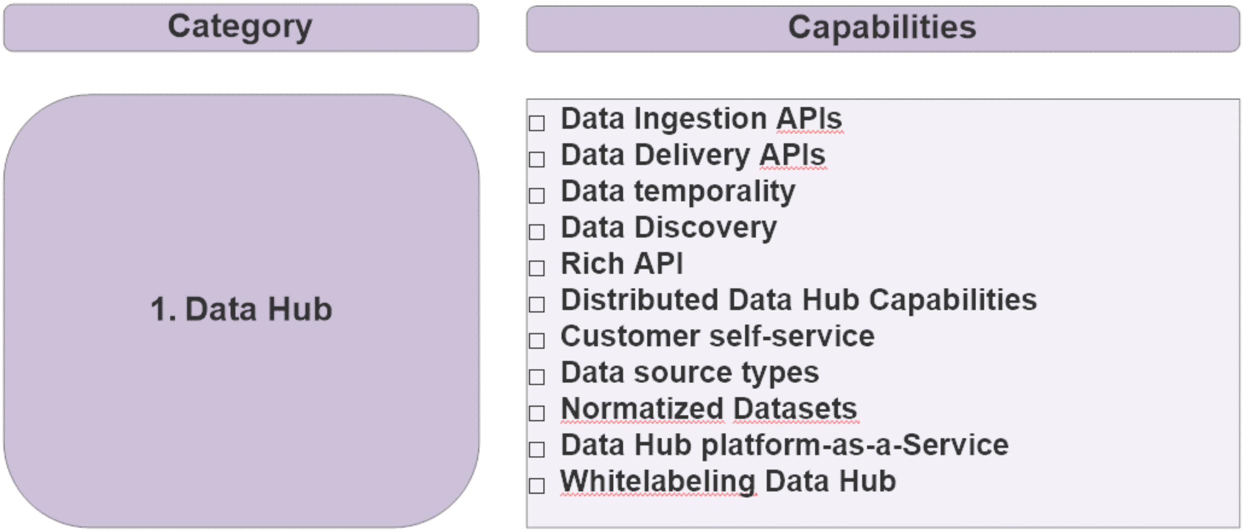


*Figure 7 Capabilities for category Data Hub in TM Forum supporting capabilities*

## 3.3 City Platform Capabilities: CIP

When the EIP-SCC OUP and TM Forum maps are compared, it becomes clear that a combination of the capabilities in both offer the most valuable input for the CIP architecture. In Chapter 5 the five CIP components will be discussed in relation to the most relevant capabilities in both frameworks.

# 4. CIP-Stakeholders

An open urban platform ecosystem is an economic community supported by a foundation of interacting stakeholders (TM Forum, 2017). Understanding the stakeholders in the ecosystem, their demands and their drivers, is essential to identify and define functional requirements. It is also essential for creating an appropriate governance model and business framework: who has access to which data, under which conditions? Who is responsible for security or privacy measures?

The initial description of the CIP was focused on three stakeholders: the (1) Data Platform Owner that facilitates (2) Data Providers and (3) Data Users. But the City Innovation Platform, as part of the IRIS-project, is itself connected to other platforms through a federative network. Therefore, new stakeholders arise with their own requirements in terms of ownership, security, service levels, etc. Merely looking at the City Innovation Platform as a technical solution to collect and provide data would be short of all relationships and interests concerned. The scheme below shows the different stakeholders in the CIP ecosystem.

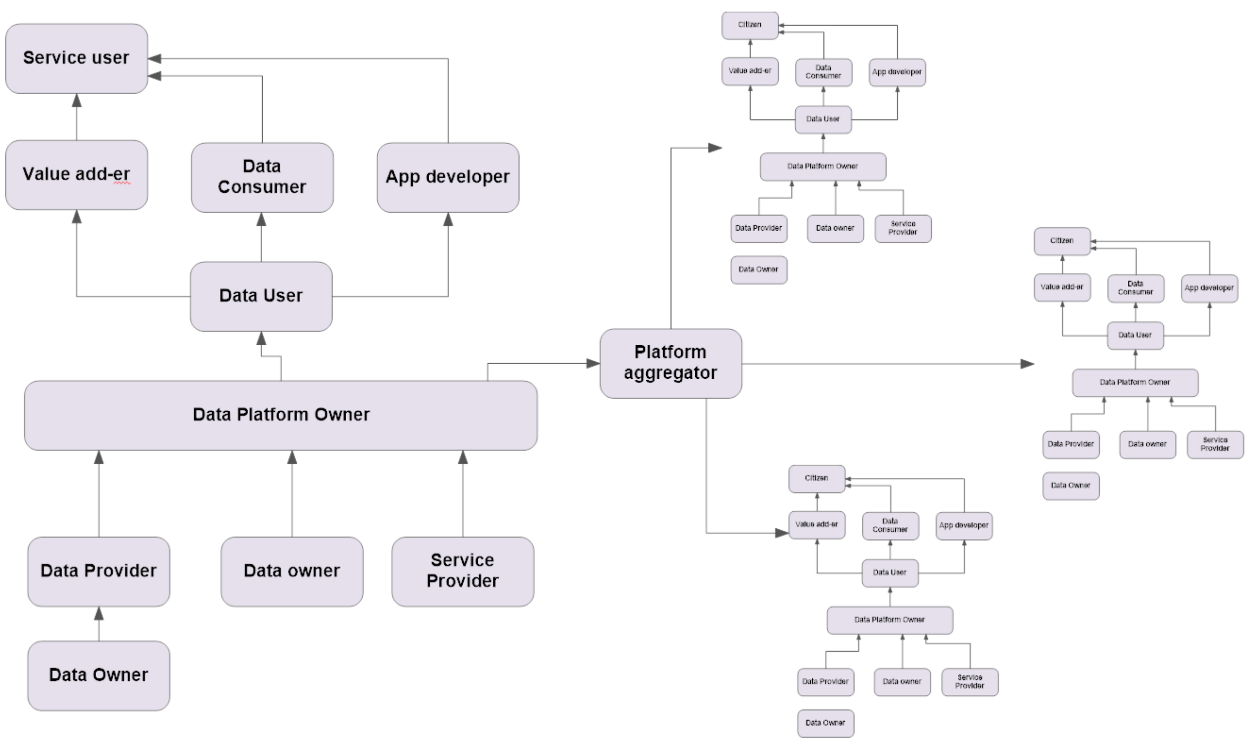


*Figure 8 Stakeholders  in City Innovation Platform ecosystem*

Each stakeholder has different demands regarding the platform. The table below gives a first overview of the demands of the different stakeholders and are not meant as an exhaustive list. The demands are described in general terms and are meant to be used in next chapters to connect them to platform capabilities, CIP-components and platform scenario´s.

| Stakeholder/Role | Demands |
|---|---|
| Data provider | - Possibility to connect and upload data<br>- Different means for exchanging data (API, upload, ETL)<br>- Findability of data (metadata)<br>- Agreement about data ownership (licences)<br>- Service Level agreements<br>- Secure infrastructure (auditable)<br>- Device management<br>- Insight in data usage (metrics) |
| Data Owner | - Control over data<br>- Insight in data usage (metrics) |
| Service providers | - Guarantees about availability of data<br>- Secure infrastructure<br>- Control who gets access to data<br>- Guarantees about ownership of data |
| Data User | - Reliability of data (accuracy, maintenance)<br>- Data quality<br>- Different means to access data (API, download) |
| Data consumers | - Understanding of meaningful services<br>- Understandable data |
| Data Platform Owner | - Maintainability<br>- Service Level Agreements<br>- Compliancy with laws, regulations, privacy rules |
| Data value adders | - Standardized data<br>- License model that supports new business models<br>- Marketplace for data |
| App developers | - Service level agreement<br>- Data quality<br>- License model that supports new business models |
| Platform aggregators | - Exchange based on open standards<br>- Possibility to add value |
| Service User | - Understandable information<br>- Equal access |
| Policy maker | - Compliance with rules, laws and regulations (e.g. GDPR)<br>- Is a Privacy Impact Assessment executed?<br>- Are Privacy by Design guidelines followed? |

*Table 3 Stakeholders, roles and demands*

To help us identify stakeholders, stakeholder roles, drivers, and API's (and more) in the CIP ecosystem we decided to use the CurateFX ecosystem design tool from TM Forum. The big benefit of CurateFX is that all documentation can easily be exported and reused in a structured way. Below are two examples from the CurateFX-tooling, in which stakeholders, roles and drivers are identified and connections clarified. The tool also helps to identify conflicts, and ultimately to describe the API´s that are necessary for CIP. Designing the CIP ecosystem this way helps to define what the platform must be capable of.


*Figure 9 Example of Stakeholders, roles and drivers for CIP in CurateFX*

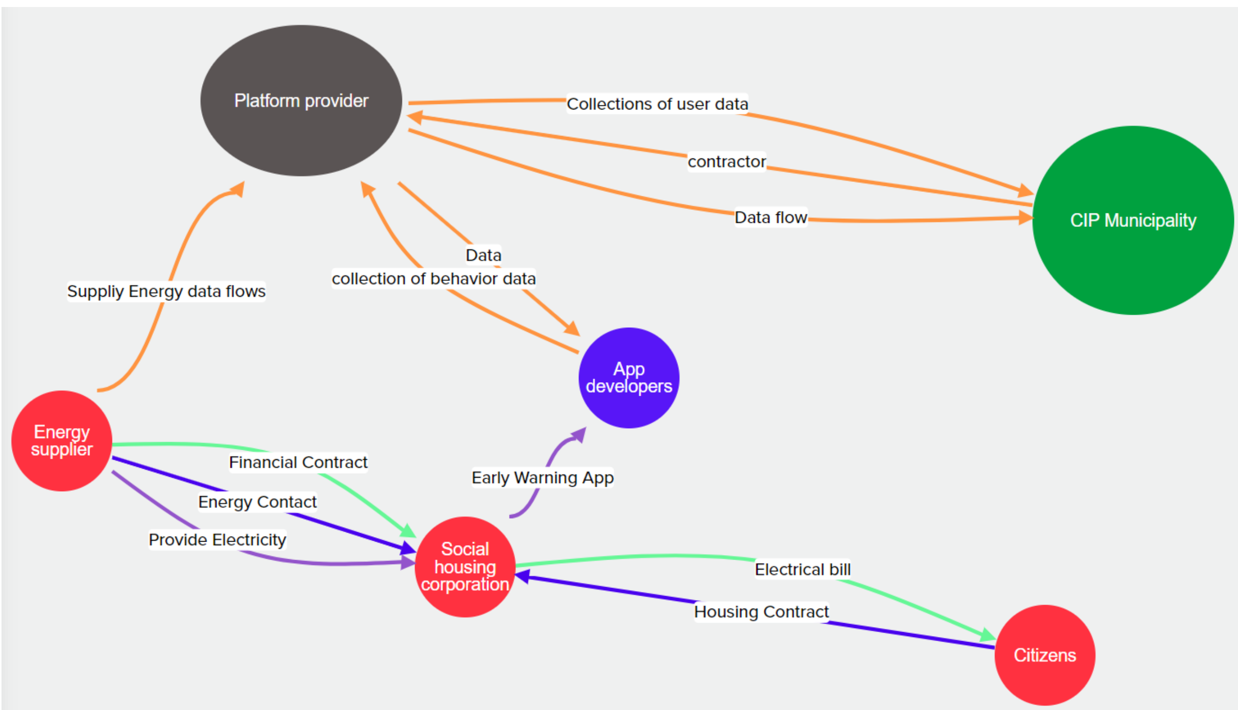


*Figure 10 Example of CIP Ecosystem design in CurateFX*

# 5. CIP Reference Architecture

Based on the Capability Maps from EIP-SCC and TM Forum, we looked how we can improve the original City Innovation Platform Architecture. In the scheme below we (roughly) plotted the EIP-SCC OUP-capabilities and TM Forum supporting capabilities onto the CIP-architecture. The numbers refer to the EIP-SSC capabilities (squares) and TM Forum capabilities (circles) mentioned in the previous chapter. In general we conclude that capabilities mentioned by both EIP-SCC and TM Forum are present in the City Innovation Platform, but not always in the same terms.

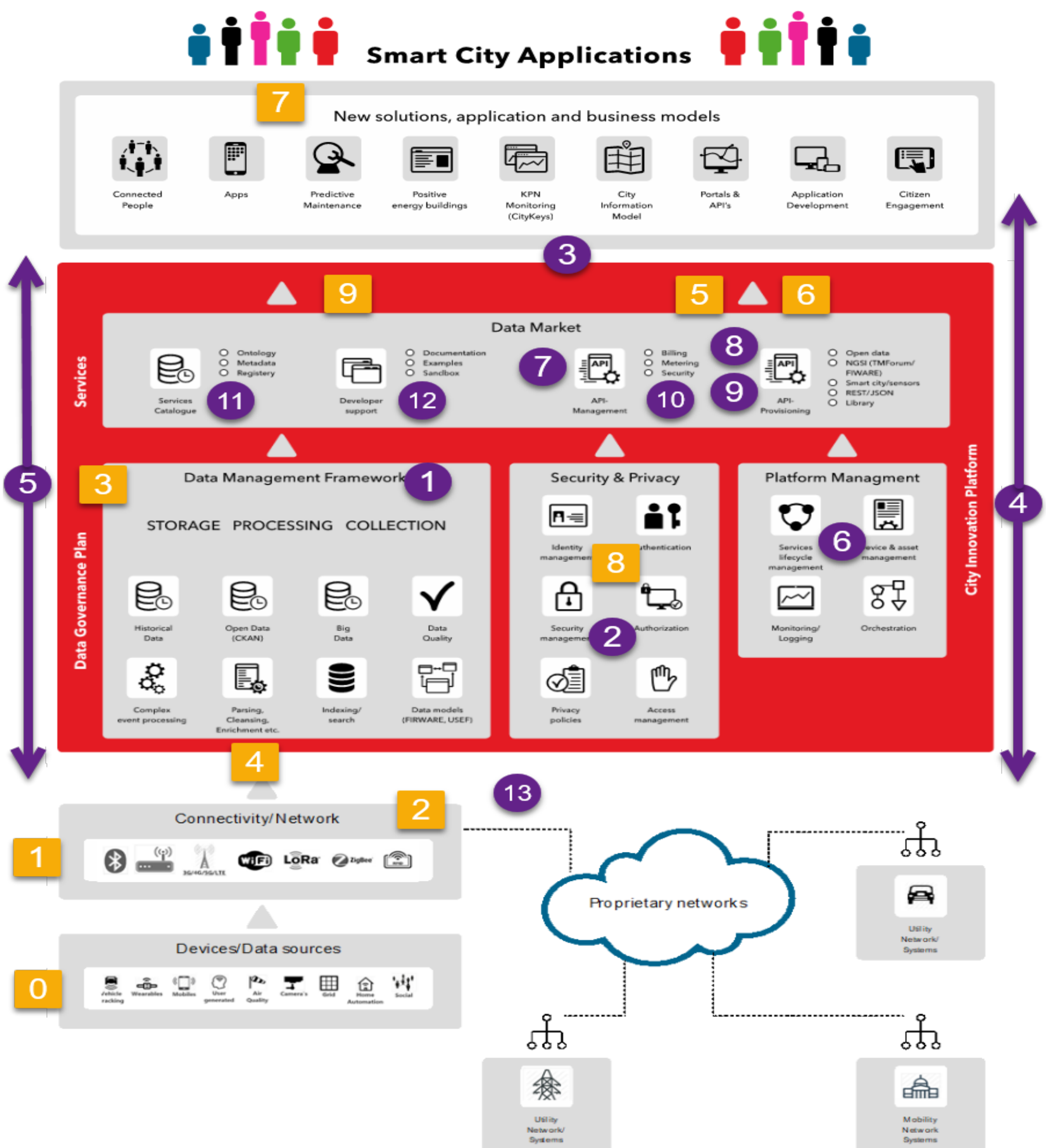


*Figure 11 EIP-SCC OUP-capabilities mapped on CIP-architecture*

The CIP does not address all categories and capabilities of the EIP-SCC OUP Capability Map or the TM Forum supporting capabilities. With the CIP we focus on EIP-SSC categories 3 (Data Management & Analytics) and 4 (Integration, Choreography and Orchestration), with some specific capabilities from categories 2 (Device Asset Management & Operational Services), 5 (Generic City / Community) and 6 (Specific City / Community), as well as the more generic category 8 (Privacy & Security). From the TM Forum supporting capabilities all thirteen categories are more less part of the CIP.

The City Innovation Platform connects to all kinds of IoT-devices and existing systems. The connectivity/network capabilities (or so called south bound interfaces) for IoT-devices use different communication protocols. These protocols provide an interface to the CIP for easy conversion of data streams. The SynchroniCity-reference architecture (Synchronicity Reference Architecture for IoT enabled smart cities (D2.1), 2017) describes a list of southbound interfaces that can be found in existing solutions and platforms. These capabilities are not structuring for the CIP architecture, but interoperability in general needs to be ensured within CIP by open communication protocol conversion or a standardized data interoperability approach.

The City Innovation Platform comprises five components, as mentioned before and shown in figure 10. These components are:

- Data management framework
- Data market
- Security and privacy
- Platform management
- Proprietary systems connectivity (federated solution)

To create a CIP Reference Architecture that follows the EIP-SCC and TM Forum standards, the next step is to match each of the five CIP-components against the EIP-SCC Capability Map and the TM Forum supporting capabilities.

## 5.1 Data management framework

A core function of the City Innovation Platform is the Data Management Framework. It needs to support multiple data sources/formats while also enabling data prioritization in an ever-expanding ecosystem of data by collecting, sorting and providing. The City Innovation Platform will offer solutions to collect, store and provision large amounts of (open, shared and closed) data, delivered by all kinds of connected objects, deployed all over the city, in addition to data produced by existing platforms and domain specific solutions (e.g. waste collection, parking, air quality, energy consumption, etc.) by companies, research labs and citizens operating in the public space.

As a starting point the City Innovation Platform will embrace and reuse open tools like the FIWARE-framework[1] and OGC-standards[2]. This does not mean FIWARE is the only or preferred solution. The CIP Reference Architecture is meant to be technology agnostic and not favouring specific technologies,

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[1] https://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php/FIWARE_Architecture
[2] http://www.opengeospatial.org/standards

products or solutions. The City Innovation Platform embraces the approach FIWARE chooses, by adopting open innovation with Generic Enablers, Data models, open API's and collaboration with other parties.

The CIP Data management framework focuses mainly on managing the data workflow: from acquisition of data, to processing and finally exploitation. From a capabilities perspective this resembles the topics mentioned mostly in EIP-SCC capability categories 3 (Data Management & Analytics) and 4 (Integration, Choreography and Orchestration) and TM Forum category 1 (Data Hub). To fulfil the capabilities in EIP-SSC categories 3 and 4 and TM Forum category 1, there are several existing components that can be used. The exact solution to meet the requirements is out of scope, because that's about the "How" instead of "What". It can be fulfilled with multiple different, open (technical) solutions. The descriptions below provide a more detailed view on Data Management in the CIP Reference Architecture (in comparison with existing Reference Architectures).

#### *5.1.1 (Open) data publication (EIP cap 3.14), and open data (EIP cap. 5.3)*

These capabilities about open data are about making the growing pools of data available/accessible to "data consumers". Data publication may occur in several data formats (preferably standards based), in real-time or batch-oriented, and through several communication channels and protocols (also related to TM Forum Datahub category, data source types).

Each of the Lighthouse cities is using CKAN[3] for their open data portal. CKAN is a data management system that makes public and private data accessible – by providing tools to streamline publishing, sharing, finding and using data. CKAN can be used in different ways within the reference architecture. For example, the Dutch National Open Dataportal[4] uses CKAN as a register. No data is stored in CKAN, but it shows the metadata (based on DCAT-AP) and refers to the location of the original source. The Data platform used by the City of Utrecht, is also based on CKAN[5], but stores data as well and provides an API to connect to the data.

CKAN is mainly used for open data, to support collaboration, transparency and innovation opportunities between a city and community actors. Open data is preferably formatted and defined by applying relevant standards, including standards for linked data/semantic web. More on open data can be found, for example, in the Open Data Goldbook[6].

CKAN is a suite of different components. It is extendible with different plugins. Compliance to the DCAT-AP metadata-standard is handled by a specific plugin[7] (capability 3.15). Connections between municipal, national portals and the EU-portal are based on DCAT-AP. This is only about open data. To store data, CKAN offers the Datapusher plugin[8], so data can be stored in PostgreSQL-database for example. For search, CKAN uses SOLR (capability 3.21).

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[3] https://ckan.org/
[4] https://data.overheid.nl
[5] https://utrecht.dataplatform.nl/
[6] Open data goldbook for data managers and data holders - practical guide for organisations wanting to publish data, 2018
[7] https://github.com/ckan/ckanext-dcat
[8] https://github.com/ckan/datapusher

For the publication of (open) data, the use of standards (capability 5.2) is of great importance. But we have to be specific in what we mean, because there is a lot to standardize (ODI, 2018), as shown in the scheme below. Within CIP we make a distinction between data models, data formats and API´s.

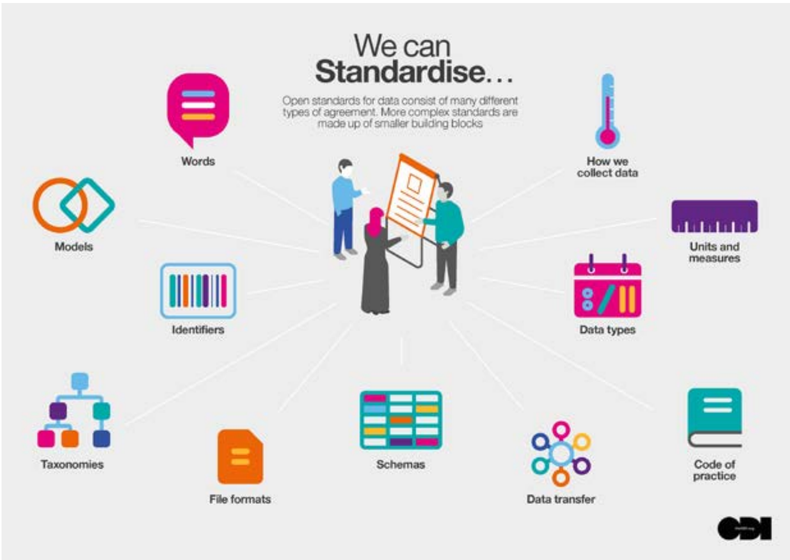


*Figure 12 Standardization of data concerns many topics*

### *5.1.2 File or data formats (EIP cap 3.14)*

An open file format is one where the specifications for the software are available to anyone, free of charge, so that anyone can use these specifications in their own software without any limitations on re-use imposed by intellectual property rights[9]. The benefit of open file formats is that they permit developers to produce multiple software packages and services using these formats. This then minimizes the obstacles within the CIP to reusing the information they contain.

The preference from a data perspective also is that information be released in open file or data formats which are machine-readable. The table below gives an overview of these open formats.

| Format | Description |
|---|---|
| JSON | JSON is a simple file format that is very easy for any programming language to read. Its simplicity means that it is generally easier for computers to process than others, such as XML. |
| XML | XML is a widely used format for data exchange because it gives good opportunities to keep the structure in the data and the way files are built on, and allows developers to write parts of the documentation in with the data without interfering with the reading of them. |
| RDF | A W3C-recommended format called RDF makes it possible to represent data in a form that makes it easier to combine data from multiple sources. RDF data can be stored in |

[9] http://opendatahandbook.org/guide/en/appendices/file-formats/

| | |
|---|---|
| | XML and JSON, among other serializations. RDF encourages the use of URLs as identifiers, which provides a convenient way to directly interconnect existing open data initiatives on the Web. RDF is still not widespread, but it has been a trend among Open Government initiatives, including the British and Spanish Government Linked Open Data projects. The inventor of the Web, Tim Berners-Lee, has recently proposed a five-star scheme that includes linked RDF data as a goal to be sought for open data initiatives. |
| CSV | Comma Separated Files can be a very useful format because it is compact and thus suitable to transfer large sets of data with the same structure. However, the format is so spartan that data are often useless without documentation since it can be almost impossible to guess the significance of the different columns. It is therefore particularly important for the comma-separated formats that documentation of the individual fields is accurate.<br><br>Furthermore, it is essential that the structure of the file is respected, as a single omission of a field may disturb the reading of all remaining data in the file without any real opportunity to rectify it, because it cannot be determined how the remaining data should be interpreted. |
| TXT | Plain text documents (.txt) are very easy for computers to read. They generally exclude structural metadata from inside the document however, meaning that developers will need to create a parser that can interpret each document as it appears. |

*Table 4 Description of open file formats*

For geographical file and data formats, like CityGML, WFS/WMS, KML and GeoJSON we refer to the extensive list of standards defined by the Open Geo Consortium.[10]

### *5.1.3 Metadata management (cap 3.15)*

Metadata management is about 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. Metadata management is of great importance for the Data Market.

The CIP supports the DCAT-AP standard, but additional information might be needed to support usage within the Data Market.

### *Data models (cap 3.12)*

Another topic that is of great importance are standards for Data Models. This is about the 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.

[10] http://www.opengeospatial.org/docs/is

For the City Innovation Platform there are a few useful implementations of data models, like the development of data models by FIWARE[11]. Currently there are data models for 12 topics:

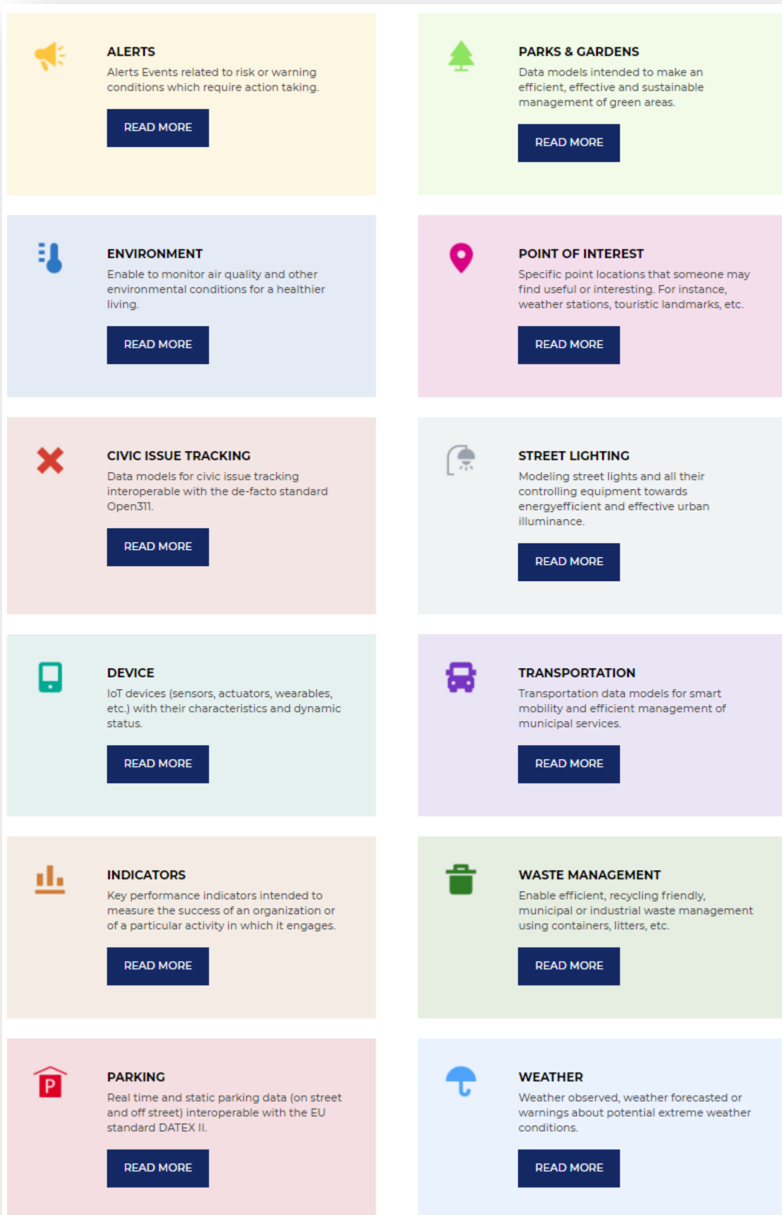


*Figure 13 FIWARE Data models*

[11] https://www.fiware.org/developers/data-models/

Some of these FIWARE data models are still in development and currently there is no specific data model for energy related topics. Within the IRIS-project we have had a look at the USEF-model, but this model is focusing more on managing grid flexibility and therefore less useful within CIP. Data generated by aggregators or other stakeholders within the USEF-framework can be connected to CIP to make them available for reuse in innovative services or new business models.

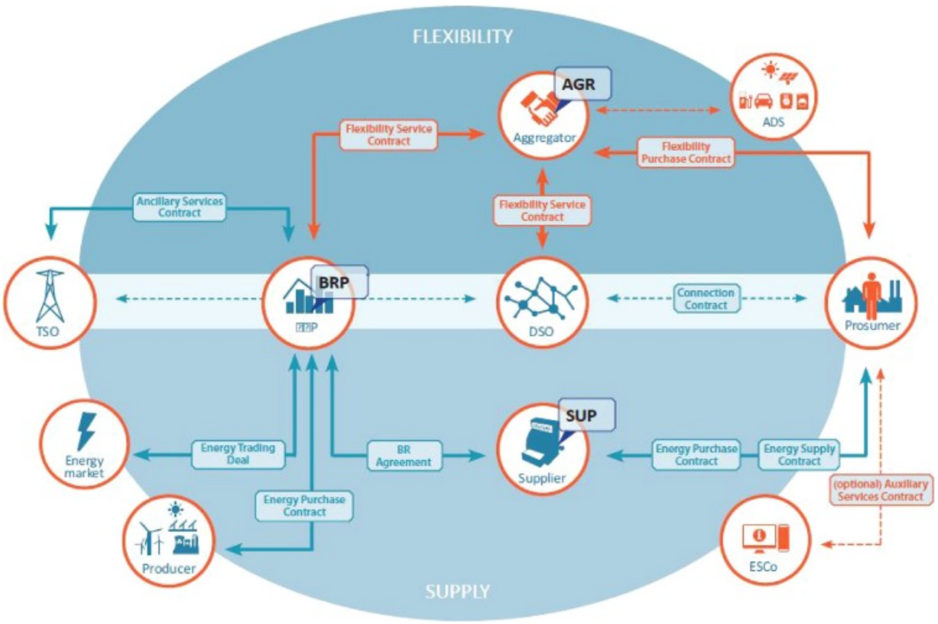


*Figure 14 The USEF-model for managing grid flexibility*

An additional data model that is important for the City Innovation Platform is the "**City Information Model" (CIM)**. The main objective of a CIM is to be able to visualize the physical city through its digital twin to create citizen engagement and minimise errors in the building process. A CIM is an extension of BIM[12], that is used to model, build and visualize buildings, bridges and streets. It is often focused on creating a 3D digital model of the entire city (relationship with WP task 7.6, Gothenburg and SlimCity Utrecht[13]). Although there is not one specific, standard CIM Data Model, the City Innovation Platform should support the development of a City Information Model by connecting or providing data, linking to available solutions, systems or services. The OGC CityGML[14]- and Land/InfraGML[15] standards are considered important contributions for creating a CIM.

CityGML and Land/InfraGML are international Open Geospatial Consortium (OGC) standards (in development) for the representation and exchange of semantic 3D city, landscape and infrastructure models. The data model behind CityGML is based on the ISO 19100 standards family and is implemented as an application schema for OGC's Geography Markup Language (GML). The CityGML standard allows

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[12] https://www.buildingsmart.org/ - Open BIM – offers an universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows.
[13] https://www.slimcity.nl/home
[14] https://www.citygml.org/
[15] http://www.opengeospatial.org/standards/infragml

the possibility of extending the standard by Application Domain Extensions (ADE). For energy modelling purposes, ADEs such as the Energy ADE4 and the Utility Network ADE5 are of great value, as they allow standardized data storage and exchange of energy relevant parameters directly in the CityGML data model. Furthermore, object modeling specifications can be shown at different Levels of Detail (LoD) ranging from simple building block models (LoD1) to full detailed building models that include building interiors (LoD4). Only the generation of LoD1 and LoD2 models from free and open data sources are considered as these LoDs are also the most common levels for representing a city wide buildings model. (Jochen Wendel, 2017)

The scope of the Land/InfraGML Conceptual Model is land and civil engineering infrastructure facilities. Anticipated subject areas include facilities, projects, alignment, road, railway, survey, land features, land division, and “wet” infrastructure (storm drainage, wastewater, and water distribution systems). This standard is still in development.

The idea of the CIM data model is to build it up from multiple schemas (OpenBIM, CityGML, Land/ InfraGML, a Common data dictionary, a Traffic Schema, etc). The CIP needs to provide Open API(s) to expose the CIM data according to the agreed schema.

#### *5.1.4 Other Data Management capabilities (EIP cap cat 3)*

Within EIP-SSC capability category 3, a lot of other data management capabilities are described. In the Technical Architecture each of these capabilities need to be specified. For most of the data management capabilities Open API’s are crucial. There are many ways to model and provide data as an API. And there are different emerging (and sometimes competing) standards:

One of the solutions is to provide real time IoT-data via the FIWARE NGSI API[16]. The FIWARE NGSI v2 API is for modelling and exchanging context data. The main elements are context entities, attributes and metadata.

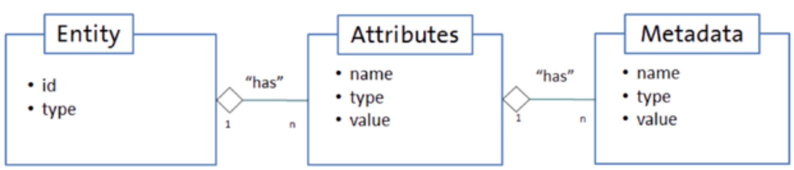


*Figure 15 FIWARE NGSI entities*

The figure on the next page gives a real world example how entities, attributes and metadata are related.

[16] http://fiware.github.io/context.Orion/api/v2/stable/

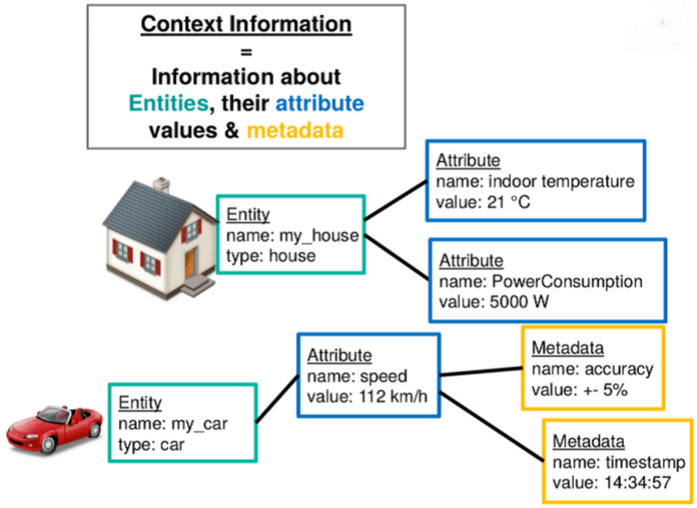


*Figure 16 NGSI context information example*

Another standard API for provisioning and modelling data, is the OGC SensorThings API.[17] This API provides an open, geospatial-enabled and unified way to interconnect the Internet of Things (IoT) devices, data, and applications over the Web. The Sensing part of this API provides a standard way to manage and retrieve observations and metadata from heterogeneous IoT sensor systems.

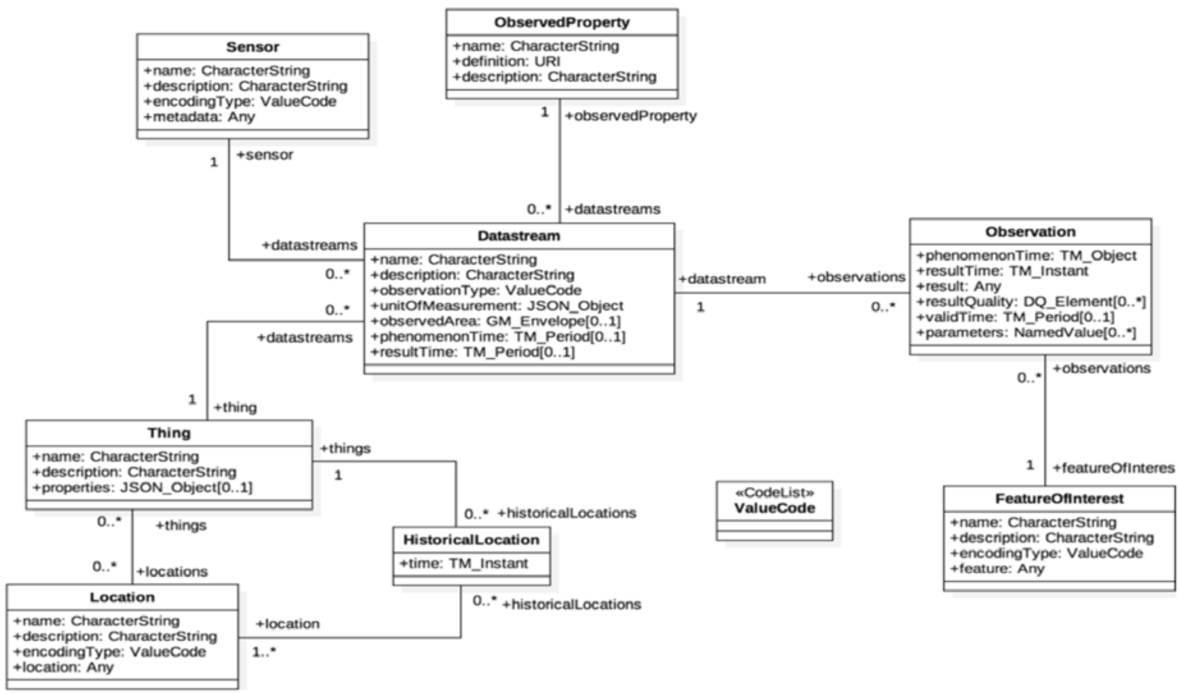


*Figure 17 SensorThings sensing entities*

Besides the modelling and provisioning of API´s, there is a broader need for API-management (see Data market).

## 5.2 Data Market

A second component of CIP is the Data Market. A Data Market place or Data Market is an online store for different data products and types (open, commercial datasets and information products) from different sources/organisations and aimed at different users. Data types can be mixed and structured in a variety of ways and can be made available as download, API or other arrangements. Data Markets are aiming to facilitate data consumers, like developers, journalists or consultancy agencies, to create new business opportunities. Examples of Data Markets are Open Weather Map or the Copenhagen Data Exchange.

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[17] http://docs.opengeospatial.org/is/15-078r6/15-078r6.html

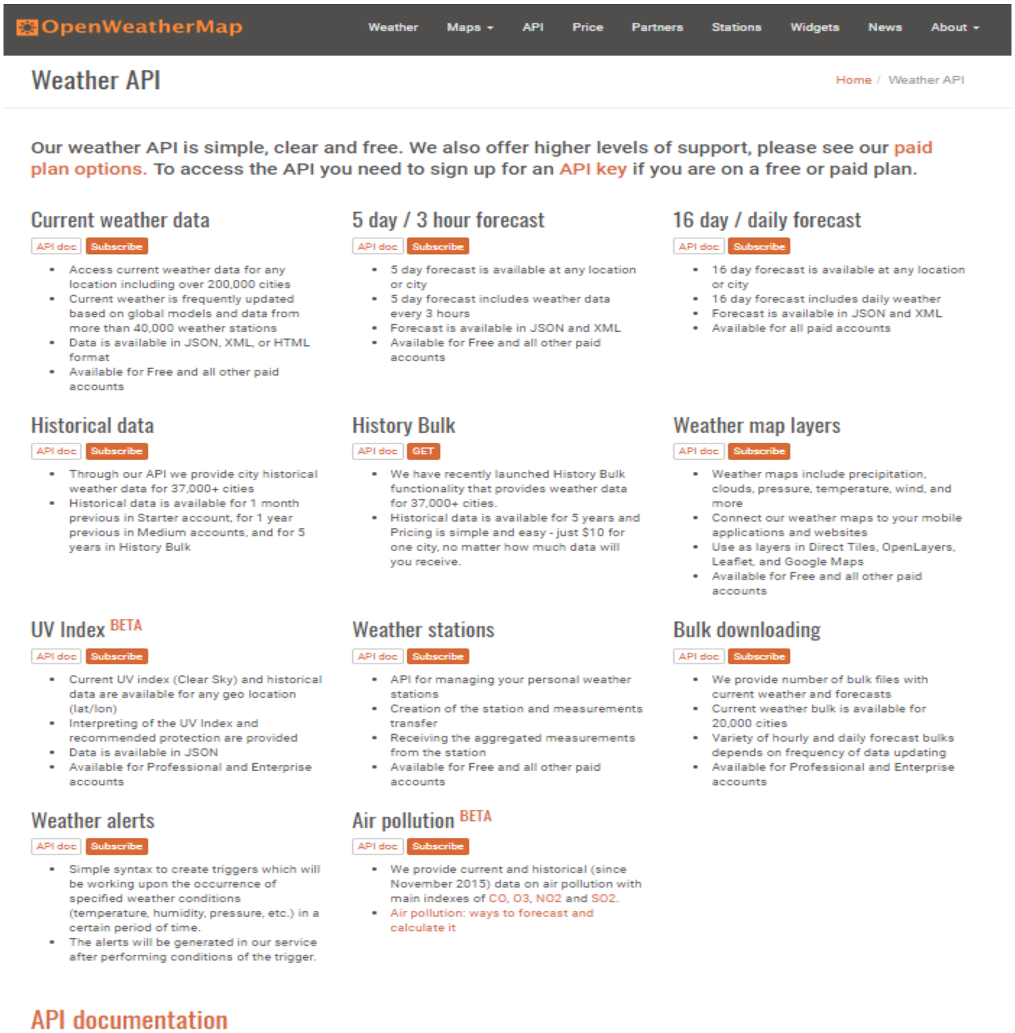


Figure 18 Open Weather Map example of a Data Market[18]

[18] https://openweathermap.org/api

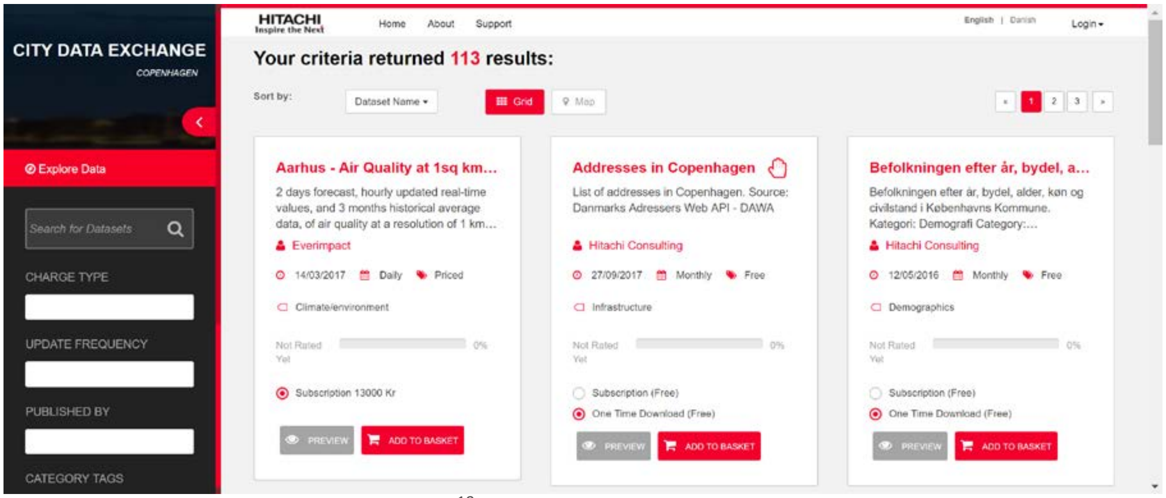


Figure 19 The City Data Exchange Copenhagen[19]

Data exposed in the Data Market can be used by all kinds of organisations: government, business and consultancy agencies and many types of analysts/developers. Data marketplaces have proliferated with the growth of big data, as the amount of data collected by governments, businesses, websites and services has increased and all that data has become increasingly recognized as an asset.

The main goal of the Data Market within CIP is to provide support for realizing integrated solutions, new business models and applications. It does so by supporting the use of data in many different ways. The CIP Data Market has three functions:

1. It provides a point of discoverability and comparison for data, along with indicators of quality and scope.
2. It offers ready to use data (high quality, high usability)
3. It provides an economic model for broad access to publish and consume data and create new business models.

There are different challenges to create a vibrant CIP Data Market: usability, usefulness, quality, potential monetization, impact assessment (quantification of advantages). Data should be user friendly, and user trust needs to be sought (catalyst organization). (Espresso, 2016).

To face the challenges mentioned above, the CIP looks at different EIP-SCC OUP capabilities that are needed to create a coherent and integrated architecture to facilitate the CIP Data Market. The Data Market can only exist when at least the following capabilities are available within the CIP.

| Nr | Capability |
|---|---|
| 3.10 | Data Security Management |
| 3.14 | (Open) Data Publication |
| 3.15 | Metadata Management |
| 3.17 | Analytics |
| 3.18 | Reporting and Dashboarding |

[19] https://www.citydataexchange.com

| | |
|---|---|
| 3.19 | (Geo)visualisation |
| 3.21 | Integral Search and Navigation |
| 4.4 | (Open) API Management |
| 4.7 | Transaction Management |
| 4.9 | (API) Service management |

As a starting point, the CIP Data Market should provide an overview of all available (inter)national and city-level data within CIP or as provided by external services in a Data Registry (Services Catalogue). This can, for example, be based on CKAN with support for the DCAT-AP metadata standard. Such a Data Registry is interoperable with national and EU open data portals. The CIP Data Market will help to create a symbiosis between data from different entities.

There are already several more extensive, existing (open) initiatives that provide input for the Data Market. These solutions can be used for the CIP Data Market. One example is the Data Market solution provided by FIWARE[20]. This setup utilizes CKAN as the Data Catalogue where data can be published, discovered, managed, and consumed. Not only static datasets (CSV, XLSX, etc) are supported, but also real (right) time context information can be published in CKAN as Context Broker queries. To use this solution there are additional components required, like the Biz Ecosystem Generic Enabler (GE). This GE allows to manage the access and monetisation of published datasets. The following picture shows the architecture used by FIWARE Data Market.

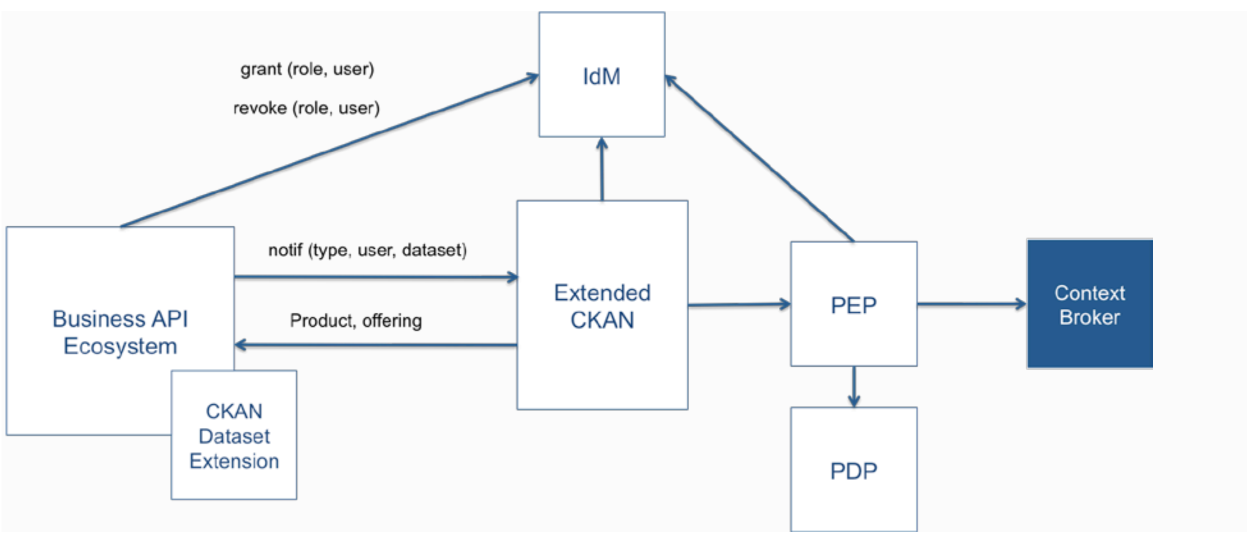


*Figure 20 FIWARE Data Market*

As the image shows, there are multiple components required and integrated in order to manage and monetize data:

- Extended CKAN: Used for the publication of the static datasets and the Context Broker queries.
- Biz Ecosystem: Used for the creation and acquisition of data offerings, including customer charging, and access grant

[20] http://fiwaretourguide.readthedocs.io/en/latest/publishing-open-data-in-fiware/fiware-extended-ckan/

- IdM + PEP + PDP (Security Framework): Used for the provision of identities, authentication, and authorization of users.

For those scenarios where the dataset is not completely open, or it is wanted to be monetized, the context broker instance must be secured using a security framework.

Within the Data Market there is an important role for (open) API´s[21] and API-management, as mentioned (for example) in EIP-SCC capability 4.4 (Open) API management and other capabilities like 4.5 till 4.10.

By using, endorsing and requiring a suite of common industry Open APIs, a range of growth and efficiency opportunities can be unlocked, as is described in the Open API Manifesto[22]. In this Manifesto is stated that using extensible Open APIs to expose a catalogue of capabilities to partners and developers, contributes to monetize existing capabilities and drive innovative new products and services. Therefore, it helps to endorse TM Forum Open APIs (see Annex 4) as a fundamental element of the CIP architecture.

API management is the practice an organization implements to manage that the APIs they expose, either internally or externally are consumable, secure, and available to consumers in conditions agreed upon in the APIs terms of use. An open API-management strategy has to be an important part of the CIP Architecture, and of the Data Market in particular. API-management requires tools and solutions to provide and manage those API´s. The following functionality is considered to be a part of API management capabilities (Wood, 2016).

| Functionality | Description |
|---|---|
| **Registry** | The key to effective API management is having an inventory of available APIs that allows API consumers to digest the characteristics of the APIs available, like its features and metadata, its structure, its capabilities and its sensitivities. The API-registry helps also to manage the lifecycle of an API, cataloguing the supported versions and their promotion or retirement.<br><br>The API registry is preferably a discrete component specifically implemented to harbour the API knowledge. But the Registry can also be manifested within other components in the Reference architecture (most likely the Developer Portal). |
| **Gateway** | The API Gateway is a mean to act on the registry, exposing the APIs therein to internal and/or external consumers. It is a server that acts as an API front-end, receives API requests, enforces throttling and security policies, passes requests to the back-end service and then passes the response back to the requester. The gateway often includes a transformation engine to orchestrate and modify the requests and responses on the fly. A gateway can also provide functionality such as collecting analytics data and providing caching. The gateway can provide functionality to support authentication, authorisation, security, audit and regulatory compliance.<br><br>In order to expose, secure, and manage an organisation's APIs the API Gateway clearly needs to work in collaboration with the API Registry, ingesting |

[21] See also the report on the "Open API recommendations for cities" from 6 Finnish cities (6Aika, 2016)
[22] https://www.tmforum.org/open-apis/open-api-manifesto/

| | |
|---|---|
| | information about the APIs and how they should be exposed. The API Gateway should also establish a feedback loop, supplying the API Registry with management-level statistics on API utilisation, in order to help maintain an accurate picture of how the organizations APIs are used. |
| **Publishing tools** | A collection of tools that API providers use to define APIs, for instance using the OpenAPI specification, generate API documentation, manage access and usage policies for APIs, test and debug the execution of API, including security testing and automated generation of tests and test suites, deploy APIs into production, staging, and quality assurance environments, and coordinate the overall API lifecycle. |
| **Developer portal** | The Developer Portal works in collaboration with both the API Registry and API Gateway to provide the information that developers need to correctly understand the organization's APIs. It provides the human interface to the APIs, providing a quality user experience and helpful tools and resources for building applications that consume the API. It offers the facilities for developers to manage their engagement with the organization. |
| **Reporting and analytics** | API management should be the system of record for **API utilisation**, embellishing the catalogue with information regarding the actual runtime behaviour and characteristics of a given API in the form of metrics determined against key performance indicators. This information may include the number of API keys registered, average and peak requests per second, and so on. The information will also be used to help both monitor and monetize the APIs exposed. |

*Table 5 API-management capabilities*

All the components mentioned above should be part of the CIP-architecture, although they may be manifested in different ways depending on the API management solution.

## 5.3 Security and Privacy

In regard to the CIP Reference Architecture the Security and Privacy capabilities apply to all layers. CIP supports security and privacy at multiple points across the hardware and software components and complies with the GDPR[23]. One of the important subjects within GDPR is privacy by design. The GDPR requires:

- the use of Privacy-by-design (PbD),Privacy-by-default and Privacy Impact Assessment (PIA) in the design of ICT systems involving personal data processing,
- the nomination of data protection officers for all public authorities and companies processing personal data for more than 5000 data subjects.

The PRIPARE[24]-handbook[25] about Privacy Management in Smart cities and Communities (Kung, 2016) contains guidelines, existing standards, practices on privacy engineering and provides an analysis of Smart cities and communities ecosystems in terms of privacy management needs. This information will be used when the CIP technical Architecture is developed (D4.4).

The scheme below shows stakeholders (and their roles) that are involved in smart city ecosystems from a privacy perspective. It's important that the different stakeholders (data controllers, data processors, integrators and other suppliers) manage obligations in procurement contracts, apply PIA/PbD-principles and comply with legal obligations. All services that interact with citizens, should inform them about the purpose and ask for their consent.

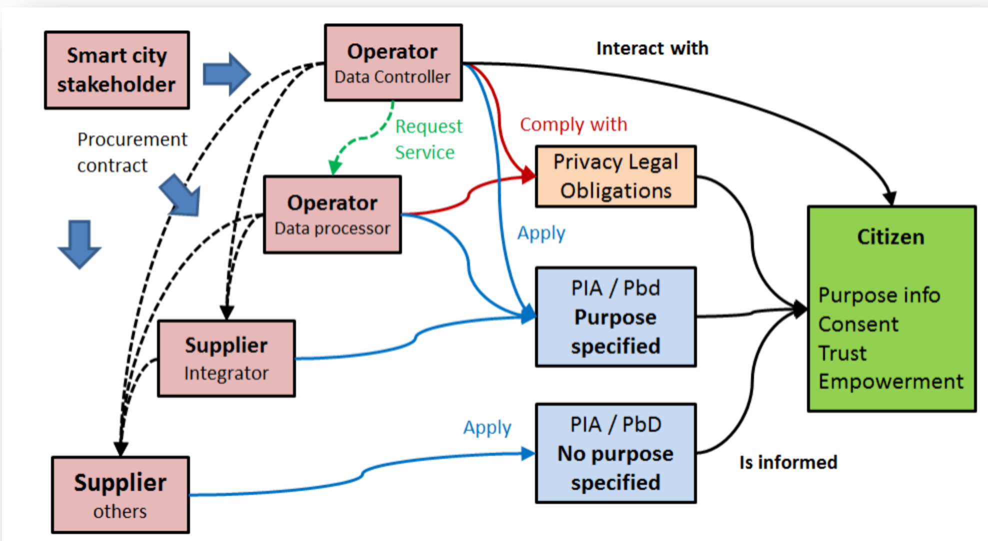


*Figure 21 Stakeholders in smart cities ecosystems related to privacy*

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[23] In Europe the General Data Protection Regulation of GDPR was published on May 4th 2016. It will have to be applied by May 25th 2018

[24] PReparing Industry to Privacy-by-design by supporting its Application in Research

[25] (Pripare Privacy- and Security-by-Design Methodology Handbook, 2016)

Functional and technical requirements of the CIP Reference Architecture are only a small part of Privacy and Security. Many measurements are related to (work)processes or organisational policies The CIP Reference Architecture will facilitate the compliance with security and privacy, regarding (at least) the capabilities mentioned in the table. Besides that, there are specific items about data privacy protection and access control that need attention within CIP.

| | | | |
|---|---|---|---|
| **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 authorisation, 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. |
| | 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. |

### *5.3.1 Data Privacy Protection (cap 3.9) and Data Security Management (cap. 3.10)*

Capability 3.9 in the EIP-SCC OUP Capability Map is about Data Privacy Protection and states "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."

Capability 3.10 is about Data Security Management and states "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.

Within the TM Forum capabilities Security and Privacy is category 4. All categories are related to APIs.

The CIP will follow Privacy Principles as described in the seven principles of Ann Cavoukian (Cavoukian, 2011): pro-active not reactive, privacy as default setting, PbD, positive sum, security, transparency and user centric. Also the ISO 29100 standard offers guidance for the functional and technical requirements of the CIP. The ISO standard mentions: consent and choice, purpose, collection limitation, data

minimalization, use limitation, accuracy and quality, openness/transparency/notice, individual participation and access, accountability, security
The general privacy principles need to be turned into privacy management services requirements (OASIS PMRM-standard[26]). This methodology will be used for the different use cases within the IRIS-project. The approach is to specify use cases, to consider privacy principles and come up with privacy service requirements, following the service categories listed below.

| Service | Purpose |
|---|---|
| Agreement | Management of permissions and rules |
| Usage | Controlling personal data usage |
| Validation | Checking personal data |
| Certification | Checking stakeholders credentials |
| Enforcement | Monitor operations and react to exceptions / Accountability |
| Security | Safeguard privacy information and operations |
| Interaction | Information presentation and communication |
| Access | Data subject access to their personal data |

*Figure 22 PMRM services*

Based on the services above, two different design strategies can be used: data collecting strategies and data processing strategies. Each strategy can be associated with different types of privacy control decisions: architecture decisions or Privacy Enhancing Technology (PET) decisions.

### *5.3.2 Access Control (cap. 8.2)*

An important building block within the CIP Reference Architecture is Identity & Access Management (IAM). Owners of data want guarantees about how their data is protected and used, for example because of privacy- or competitive reasons.

The IAM solution has to operate in a federative context: identities, authentication and authorisation have to be used across borders of individual platforms. Think about single sign-on, but also authorising users on a different platform.

Access Control is about the capability to manage general system access control that includes:

- user authorization: determine user privileges or access levels
- user authentication: proving user identity
- user management: define, collect and store user related information
- access approval
- audit

[26] OASIS, Privacy Management Reference Model and Methodology (PMRM) Version 1.0 (OASIS, 2012)

Within the TM Forum supporting capabilities this matches with Category 2 “Identity and Profile Management”.

## 5.4 Platform management

This component of the CIP-architecture is aimed at supporting device and asset management for things, sensors and other devices. The idea behind this component is that there are so many devices to monitor or patch into the platform. Therefore there is great value in streamlining the process of managing them. Devices do not exist in stasis. They are in continual need of management, reconfiguring, updates and setting control. Remote access via services offered by or through the City Innovation Platform is essential to their economic viability. The Platform management architecture must be bi-directional and flexible to allow for all network components to be connected, observed and able to communicate.

TM Forum has developed several Open API's for facilitating distributed platform management. These API's[27] (or at least the thinking behind it) might be useful for use within the CIP-architecture. Collaborate with organisations like TM Forum is recommended to develop an accepted, standards-based architecture.

From a capability perspective Platform management combines functions described in capability categories 0 (Field Equipment / Device, 1 (Communications, Network & Transport), and 2 (Device Asset Management & Operational Services). For instance remote accessibility (0.4), device configuration (0.9) and security support (0.11), device provisioning and connection management (1.8 and 1.9), configuration synchronization (1.11), device registration & configuration (2.1), operational status monitoring (2.2), error and alarm diagnostics (2.3), device service level management & reporting (2.4) and message & command handling (2.6).

To create a flexible architecture, the idea of creating an overarching module for platform management might need consideration. Within a federated, distributed architecture it is more important to focus on agreements about exchanging information about devices and their related service levels, configurations and messaging. The use of Open API's as propagated and described by TM Forum is supporting this approach. TM Forum has described over 50 Open API's and many of them support the further development of the City Innovation Platform. An overview of all TM Forum Open API's is added in Annex 4.

[27] https://www.tmforum.org/open-apis/

## 5.5 Proprietary systems connectivity (federated solution)

Within IRIS a lot of partners are involved. Each of these partners has their own platforms, systems and applications. CIP is not aiming to replace these solutions, but is striving towards a federated network of platforms (TM Forum, Capability 13, (TM Forum, 2017)).

Each platform, system or application can exchange all kinds of data. In such a context it is good practice to prevent that each source is connected independently to all existing platforms. This would require a lot of bilateral agreements and technical development. It is more appropriate to make data from one platform also available through other platforms, based on a federative approach.

Federative data sharing means the exchange of data in a controlled way between platforms. Each platform is autonomous and the data remain under control of the owner of the platform, but the platform must comply with agreements regarding data-exchange. A federation of platforms is needed to create an ecosystem of partners (data-owners, platform suppliers, app-builders, service providers, cities, etc.) who can easily collaborate on data.

A federation of platform has its own challenges:

- Agreements between the data owner and the platform owner exist, but there are no arrangements between the data owner and other platform owners. The challenge is to prevent the necessity of all kinds of new bilateral agreements. TM Forum has experience with these kinds of challenges.
- The platform that provides the data (if it has the right) has implemented adequate identity & access management. When the same source is provided through a different platform, this is not automatically guaranteed. The challenge is that agreements around identity & access management for a data source always remain guaranteed. The challenges for identity & access management also apply for API management.
- The platform that provides the data source can no longer guarantee the availability, performance and robustness of the data-provisioning when it is delivered through a different platform.

## 5.6 City Innovation Platform capabilities and requirements

| Component | EIP-SSC Capability | | TM Forum Capability | |
|---|---|---|---|---|
| Data management framework | 3.1 | Data Ingestion | 1 | DataHub<br>• Data ingestion API's<br>• Data temporality<br>• Data source types |
| | 3.3 | Non-time series data integration & transformation | | |
| | 3.4 | Time-series data integration & transformation | | |
| | 3.5 | Data fusion | | |
| | 3.7 | (Complex) event processing | | |
| | 3.8 | Data logistics | | |
| | 3.11 | Data assurance management | | |
| | 3.12 | Data modelling | | |
| | 3.14 | (Open) data publication | | |
| | 3.15 | Metadata management | | |
| | 3.16 | Master and reference data management | | |
| | 3.21 | Integral search and navigation | | |
| | 4.5 | Rules management | | |
| | 4.6 | Event management | | |
| | 5.2 | Standards | | |
| | 5.3 | Open data | | |
| Data Market | 3.13 | Data discovery | 1 | Datahub<br>• Data Delivery API's<br>• Data discovery<br>• Rich API<br>• Customer self service<br>• Normalized datasets |
| | 4.1 | Data exchange | | |
| | 4.2 | Messaging | 5 | High availability and scalability<br>• Customer apps SLA's<br>• IoT data SLA's<br>• Datahub SLA |
| | 4.4 | (Open) API management | | |
| | 4.5 | Rules management | 6 | Configuration & activation support<br>• Activation and configuration of new services<br>• Activation and configuration of new customers |
| | 4.7 | Transaction management | | |
| | 4.8 | Process, choreography, Orchestration and monitoring | | |
| | 4.9 | (API) service management | 7 | Assurance & traceability support<br>• End-to-end SLA management<br>• Service usage tracking<br>• SLA analytics DataHub<br>• SLA breach discovery<br>• Platform digital service SLA management<br>• Platform digital service performance management |

| | | | | |
|---|---|---|---|---|
| | | | | • Data provider SLA management<br>• API traffic management |
| | 4.10 | Publish, subscription and notification management | 8 | Charging support<br>• Customer charging<br>• Data feed pricing<br>• Differential charging<br>• SLA breach accounting<br>• Ecosystem SLA accounting |
| | 4.13 | Ecosystem marketplace | 9 | Invoicing support<br>• Customer invoicing |
| | 5.2 | Standards | 10 | Payment support<br>• Supplier payment<br>• Revenue sharing |
| | 9.2 | Service management | 11 | Catalogue lifecycle management<br>• data source registration for delivery<br>• Resource monetization<br>• Data feeds with class of service<br>• API versioning |
| | 9.5 | Market interaction | 12 | On-boarding support<br>• Provider on-boarding<br>• Ecosystem enablement |
| | 9.6 | Third-party interaction | | |
| Security and Privacy | 3.9 | Data privacy protection | 2 | Identity and profile management<br>• User authentication<br>• User authorization<br>• User management |
| | 3.10 | Data security management | | |
| | 8.1 | Security governance | 4 | Security/Privacy<br>• Data privacy<br>• Licences/commercial and technical agreements<br>• White-listing of devices<br>• Data service qualification<br>• IoT-security |
| | 8.2 | Access control | | |
| | 8.3 | Privacy & security risk management | | |
| | 8.4 | Auditing | | |
| | 8.5 | Cryptography | | |
| Platform Management | 2.4 | Device service level management & reporting | 4 | Security/privacy<br>• Device management |
| | 2.6 | Message & command handling | | |
| | 9.1 | Operations centre | | |
| | 9.2 | Service management | | |
| Proprietary Systems Connectivity | 1.6 | Data communication management | 13 | Federation support<br>• federated Data Hubs |
| | 1.13 | Data communication protection & security | | |

*Table 6 Relationship between CIP-components, EIP-SSC capabilities and TM Forum supporting capabilities*

## 5.7 City Innovation Platform key principles

Like other Urban Platform reference architectures, generic principles and assumptions apply to the CIP Reference Architecture. Many of the requirements follow what is described in the EIP-SCC OUP/ESPRESSO architecture (DIN, 2017) (Espresso, 2016), the SynchroniCity Reference Architecture (Synchronicity Reference Architecture for IoT enabled smart cities (D2.1), 2017) and the TM Forum Framework (TMforum, 2018). Based on these documents, the recommendation for the CIP Reference Architecture are:

1. Reuse existing, proven reference architectures, like EIP-SCC, ESPRESSO, FIWARE, SynchroniCity, etc.
2. Develop a layered architectural approach that is technological, implementation and market structure agnostic (no vendor lock -n);
3. Decoupled and distributed components
    a. Create an iterative, evolutionary and modular architectural approach, with decoupled and distributed components, based upon real use cases and adaptation to the specific local context.
    b. Every component can be replaced easily and with a very limited impact on other components and infrastructure.
4. Interoperability and openness
    a. Resulting from a decoupled and distributed architecture, the CIP must use as many publicly accepted standards as possible for communication (open API´s) and exchanging data.
    b. The architecture must be as open as possible, regarding standards, licences, file formats, API´s, code, documentation, etc. and
    c. fully promote open standards and aim at certification and compliancy.
    d. The adoption of standardized data models facilitates the reuse of assets and solutions and avoiding vendor lock-in.
5. Ensure legacy compatibility
    a. In order to cope with the dynamic technological change, the architecture must be able to support both new and legacy components, while handling different versions of the components.
6. Focus on delivering smart services for users based on Open API´s and provide easy to use documentation, examples and quality data
    a. Access and consumption of data, applications and services through standard and open API´s facilitate the reuse of solutions thus avoiding vendor lock-in. moreover, by providing data publish/subscribe functionality the process to send and receive data in the system can be simplified and improved.
7. Enable a federated, scalable approach, to connect various urban platforms.
8. Develop a Marketplace
    a. The architecture has to provide a marketplace in which assets can be exchanged among users, based on different governance policies (API-management). Documentation and easy asset discovery are key.
    b. CIP should support (standard) data licence models that enable intended business models
    c. CIP should allow to define and manage extensible SLA for data-, API and services access
9. Make capabilities the central elements to ensure a common ground.
10. Implement privacy and security by design principles
    a. A city must be able to manage/control privacy and security needs at any moment during the life cycle.

b. Data and services can have different security requirements based on their scope. CIP should support flexible security capabilities in order to accommodate the different needs of specific target scenario´s
c. CIP should offer monitoring and audit tools and manage and define policies for data and service access control to ensure compliance.

CIP should support a huge heterogeneity in IoT-device capabilities. In order to support both new and legacy IoT devices, CIP should provide end-to-end security at the API-level (rather than dealing with how different solutions handle security).

# 6. Output to other work packages

The City Innovation Platform is the foundation for most of the projects within the IRIS-project. This Reference Architecture builds upon the analysis done in D4.1, where the current situation in the different Lighthouse cities regarding data and technical infrastructure is described. The Reference Architecture in this document describes functional requirements ("what"). In D4.4 these requirements will be translated into technical requirements and guidelines: a technical architecture ("how").

The transition tracks in WP1 rely on data provided by the City Innovation Platform to define and develop new services.

For the demonstration projects in WP5 (Utrecht), WP6 (Nice) and WP7 (Gothenburg) the City Innovation Platform architecture offers the building blocks to execute the projects, like the City Innovation Model. The goal is to create a digital 3D model of the city with real time IoT data and high quality geographical information.

CIP offers open and standardized interfaces (API's) that can be used to stimulate citizen engagement in the demonstrations through the development of apps and energy and mobility services. The data provided by CIP can be used to create real time insight for policy makers, offers time series data for historical analysis and offers the opportunity to combine different data sources to create a digital equivalent of the city (CIM).

By offering real time data from multiple different sources through open API's, The CIP enables KPI-monitoring for substantive topics (energy reduction, renewable energy growth, mobility modalities, etc.) but also for KPI-monitoring on data usage. Providing open interfaces, standardized data and different data licences facilitates the development of new business models (WP3) through the Data Market.

Important follow up tasks are the selection of the technical components to implement and further develop the CIP, based upon well described use cases (which will be described in D4.4). Also the implementation of security and privacy measurements in the whole chain (from data supply to data consumption) and the recording of these measurements in the Data Governance Plan (D4.3) are important tasks. And last but not least, the data management process from collection, storage to provisioning with open API's requires technical solutions and infrastructural choices.

# 7. Conclusions

This document describes the requirements for an integrated, interoperable and open standards based CIP Reference Architecture, facilitating governance and business modelling. These requirements are based upon an analysis of existing Open Urban Platform Reference Architectures. It specifies the stakeholders, capabilities and components involved in this architecture.

This CIP Reference Architecture is about "What", not about "How". It does not offer a technical solution architecture, nor prescriptions for technologies and software components to be used. The CIP Reference Architecture uses the methodology of EIP-SCC and TM Forum for describing the different capabilities and components (§5.6).

The functional requirements for the design and development of the City Innovation Platform have been derived by combining requirements, principles and guidelines as mentioned in the previous chapters. This set of generic, architectural system requirements highlights the importance responding to fast technological changes by having an adaptable system able to accommodate multiple emerging standards. The vision for the CIP Reference Architecture is to be mission and vendor agnostic.
In this CIP Reference Architecture the data management and service requirements primarily focus on addressing the needs of different stakeholders.

The CIP is the connection between a wide range of stakeholders, solutions and services which will all demand appropriate governance, access and responsibilities. Based on the analysis of stakeholders, capabilities and components, the first conclusion is that different strategic, technological and infrastructural scenarios for the actual implementation of an Urban Platform are possible, as is further illustrated below (§7.1.1).

## 7.1 Federation of platforms

With regard to the energy-related challenges within the IRIS-project in particular and smart city topics in general, the City Innovation Platform will operate within a federation of other platforms, from multiple vendors, connecting different stakeholders and interworking between cities. As such, the City Innovation Platform Reference Architecture will pursue the design and development of a federative, distributed and decentralized infrastructure ("System of systems") each serving a community of data and service providers. This acknowledges the fact that already a variety of platforms exist and that the City Innovation Platform is connecting with these different platforms. It provides the glue to create synergies between existing and future new systems. To realise this potential, following open standards is of key importance.

## 7.2 Platform business models

To operate and maintain a City Innovation Platform in such a heterogenous environment, cities should be clear about the underlying business models for an Open Urban Platform. There are different options, such as having the platform run by the city (municipality), building a new legal entity, contracting a service provider, or collaboration of national and local agencies in sharing the operation of an OUP. The connection between the stakeholder demands (Chapter 3) and the platform capabilities (chapter 4) is that it offers choices how to design and implement the CIP-architecture. Each implementation option has its own specific characteristics, challenges and stakeholder roles. An example is the distinction between platform owner and platform operator. The platform owner should provide trust and is a non-discriminatory facilitator between the different participants. Whereas the platform operator mainly provides quality of service, based on well-defined KPI's, like scalability, availability, data security and regulatory compliance. Each city is to decide which role they want to fulfil within the City Innovation Platform ecosystem.

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# Annex 1 Existing OUP Reference Architectures

The first step in creating a Reference Architecture for the City Innovation Platform was a desk research into existing examples. A lot is already available and it would be waste of time to reinvent the wheel for the City Innovation Platform. For the CIP Reference Architecture we looked at work that has been done by other cities and projects.

A good overview is offered by SynchroniCity (Synchronicity Reference Architecture for IoT enabled smart cities (D2.1), 2017). They made an extensive analysis of relevant standards and technologies and developed their own Reference Architecture, with building blocks, modules and interfaces that resemble the CIP-architecture (southbound and northbound interfaces, datamanagement, security, privacy and governance, IoT-management and a marketplace).

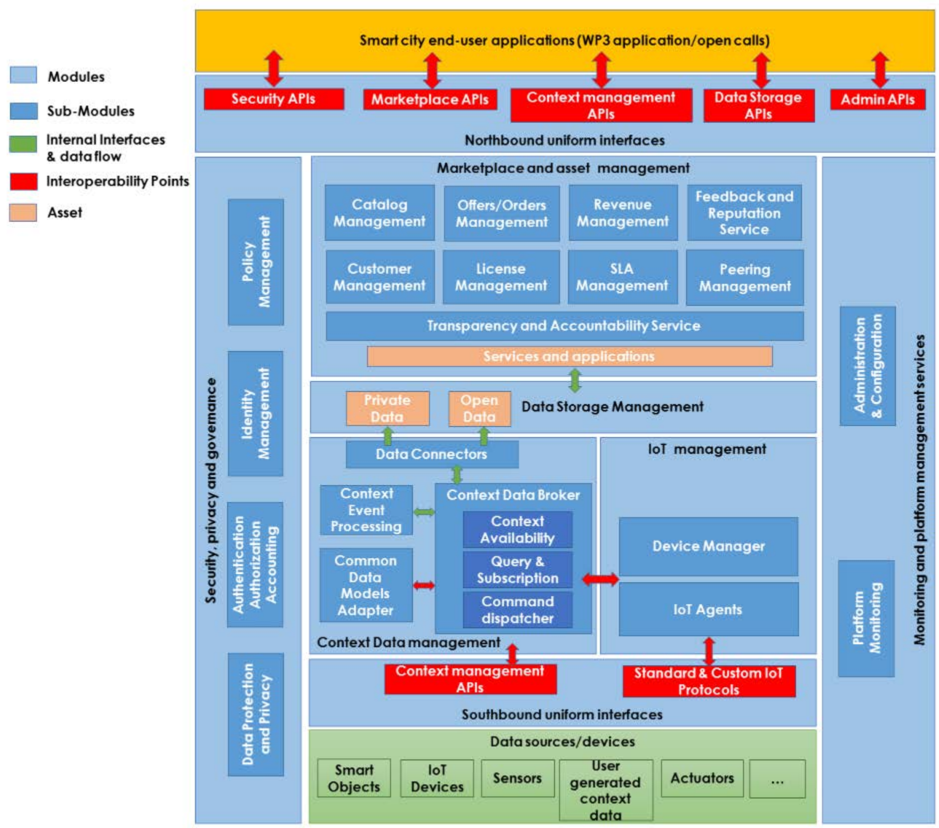


Figure 23 SynchroniCity Reference Architecture

An example of a Reference Architecture that resembles the EIP-SSC and ESPRESSO Open Urban Platforms architecture, is from the RUGGEDISED project, another EU Lighthouse-project (Rotterdam, Umea and Glasgow)[28]. It defines 11 layers with separate capabilities within each layer.In many ways, the IRIS CIP architecture follows the same architecture.

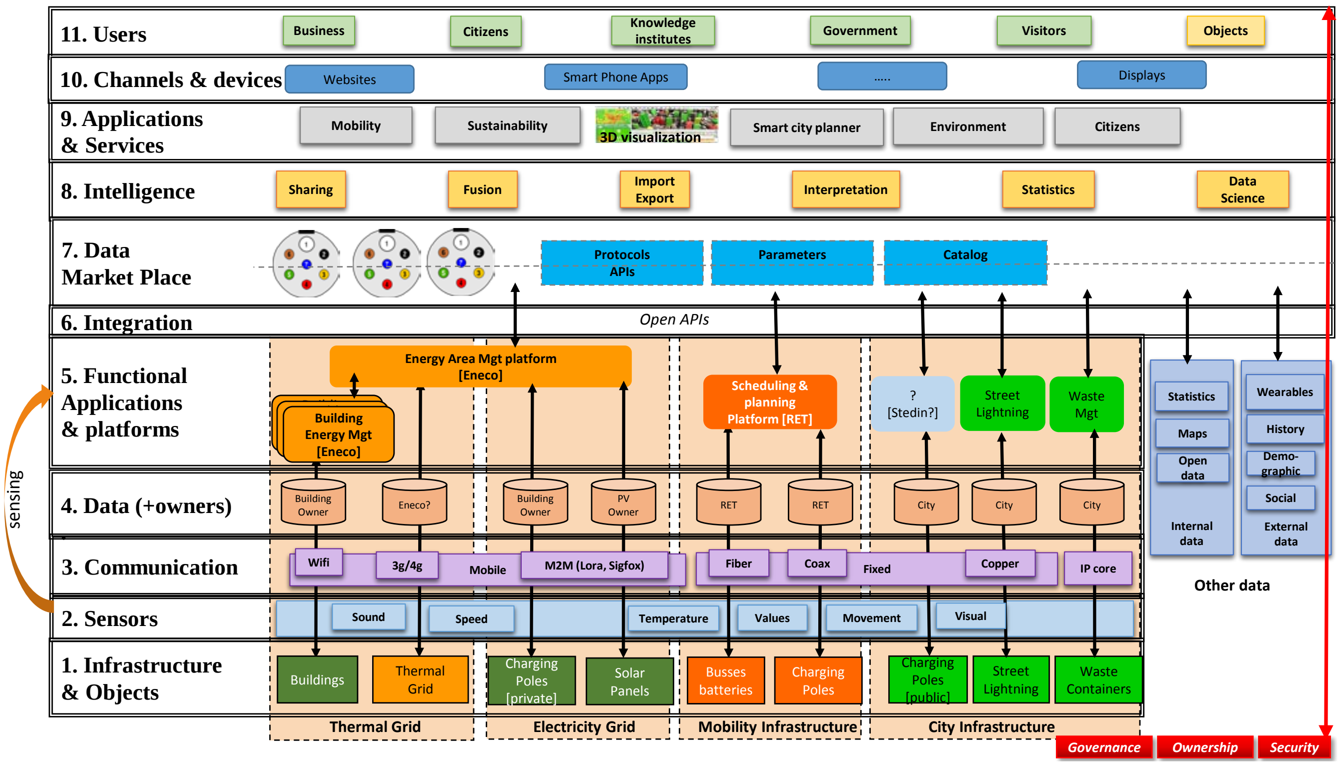


Figure 24 RUGGEDISED Reference Architecture

Because FIWARE, an open software and standards framework is adopted in CIP, the FIWARE-architecture is shown below[29].

[28] http://www.ruggedised.eu/
[29] https://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php/FIWARE_Architecture

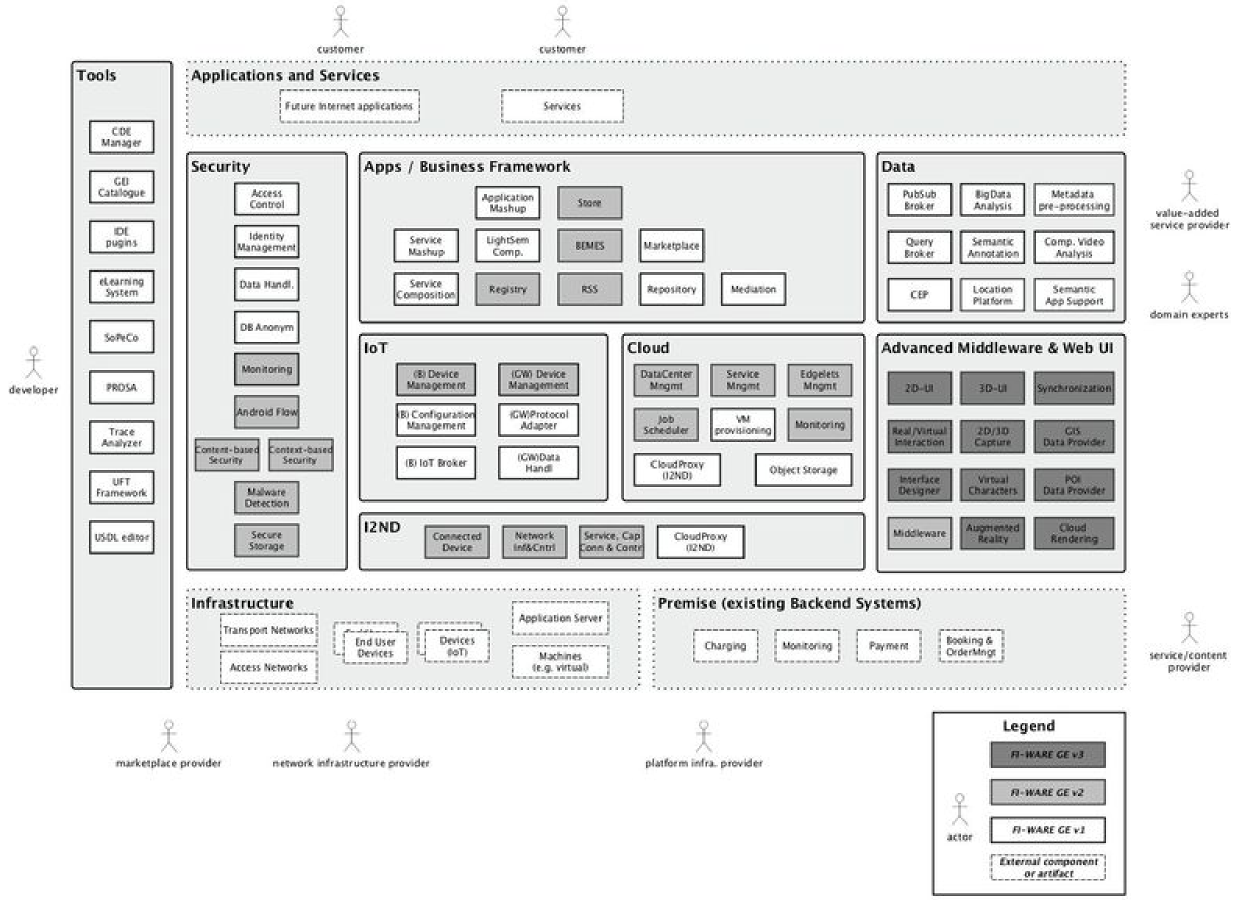


*Figure 25 FIWARE architecture*

A closer look at this architecture shows that different functions, technologies and capabilities are mixed. This interference sometimes complicates the discussion about a technology and vendor agnostic reference architecture. But FIWARE also offers valuable information about data models and Open API´s.

Another organization working on architectures for smart cities is TM Forum[30]. They described a Digital Services Reference architecture (TMforum, 2018). This reference offers more detail on the exposure and consumption of data and focuses on (open) API´s, as shown below.

[30] TM Forum is an organization focusing more and more on Smart Cities, Open API´s and Digital Architectures.

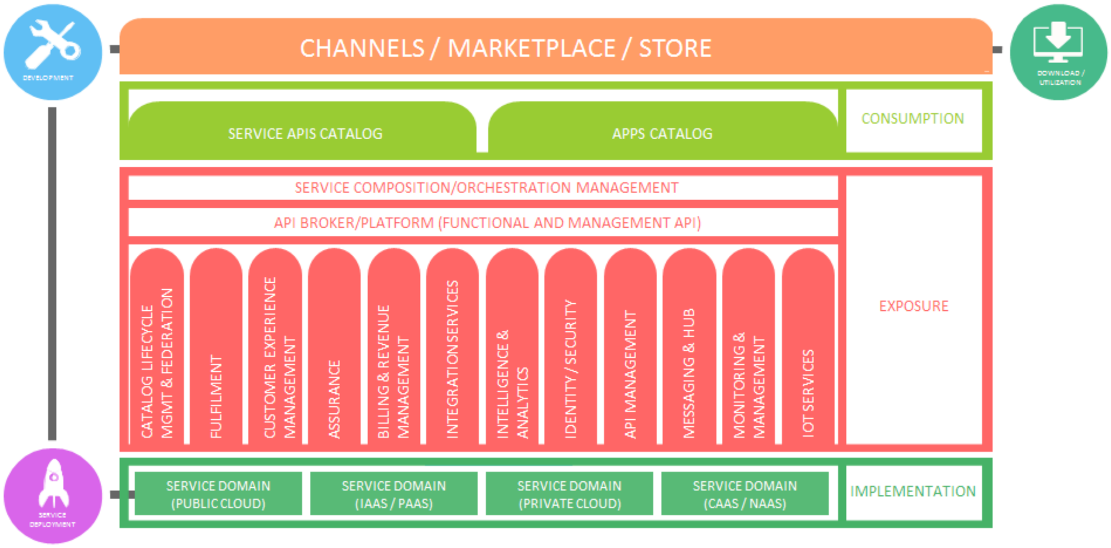


*Figure 26 TM Forum Digital Services Reference Architecture*

The examples shown in this Annex are far from complete. There is a long list of other initiatives focusing on Reference Architectures for Smart Cities and urban platforms, like OGC (Open Geo Consortium) with the Smart City Interoperability Reference Architecture (SCIRA), City Pulse - Smart City Framework, NIST - International Technical Working Group on IoT-Enabled Smart City Framework and Syncronicity - IoT Large Scale Pilot for Smart Cities and national examples like LOV-IOT in Sweden (in which the city of Gothenburg is involved).

For the City Innovation Platform we analysed these different examples and integrated them, where appropriate, in our CIP Reference Architecture.

# Annex 2 EIP-SCC OUP Capabilities

The Open Urban Platform standard contains an extensive description of the capabilities needed in a platform. It offers an overview of all the capabilities involved. The City Innovation Platform reference architecture focuses on the capability categories 3 (Data Management & Analytics) and 4 (Integration, Choreography and Orchestration). For a comprehensive and end-to-end solution, it's also important to pay attention to the other capabilities.

## Capabilities per category

For each category a set of capabilities has been identified. Their description can be found in the following table. The City Innovation Platform does not contain all capabilities in this list and has some additional capabilities that are specific for support of the goals within IRIS.

| Category | 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.) |
| | 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. |
| | 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. |
| | 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. |

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| | 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. |
| | 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. |

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| | 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<br><br>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. |
| | 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. |

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| | 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. |
| | 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. |

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| | 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. |
| | 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. |

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| | 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). |
| | 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<br>— Charge point management<br>— Tariff management<br>— Location | 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<br>— Planning<br>— Design<br>— Transactive | The built environment can become more sustainable in many ways. These include smart homes and smart buildings for energy usage and emission reduction. |

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| | 6.3 | Integrated Infrastructure & Processes<br>- Intelligent Lighting Management<br>- Multi modal Transportation Management<br>- City Information Management<br>- 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. |
| | 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. |

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| **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. |
| | 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. |
| | 9.3 | 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. |

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| | 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. |

*Table 7 EIP-SSC capabilities*

# Annex 3 TM Forum Capabilities

List of all platform capabilities organized by categories with the involved roles as mentioned in the Chapter about Stakeholders. The relationship between capabilities and stakeholders will be further developed and described within the CurateFX-tooling.

| Category | Capabilities | Business Roles |
|---|---|---|
| 1. Data Hub (Core Capabilities) | **Data Ingestion APIs:** Set of APIs to consume data from providers | • Data Provider<br>• Service Provider |
| | **Data Delivery APIs**: Set of APIs to deliver data selected data to the users | • Data Consumer<br>• App Developer<br>• Value Add-er |
| | **Data temporality:** Support of static datasets, real time data (publish-subscribe /gRPC/Event Stream), and historic data. | • Platform Owner |
| | **Data Discovery:** List of datasets and data sources available to be consumed with filters, search and selection. | • Data Consumer<br>• App Developer<br>• Value Add-er |
| | **Rich API:** support rich models for data access (queries, subscriptions, etc) | • Data Consumer<br>• App Developer<br>• Value Add-er |
| | **Distributed Data Hub Capabilities**: deploying set of platform capabilities at the edge (e.g. edge apps usage, data usage at the edge) whilst synchronising with central hub platform for matters of billing and data aggregation. | • Platform Owner |
| | **Customer self-service**: The platform must be usable by all stakeholders without any technical intervention | • Data Consumer<br>• App Developer<br>• Value Add-er |
| | **Data source types:** The platform must be able to deliver three types of data sources: only value datasets, raw datasets and devices metadata. | • Platform Owner |
| | **Normatized Datasets:** This service will provide standard data models (based on FIWARE definitions) grouping provider datasets. | • Platform Owner |
| | **Data Hub platform-as-a-Service:** A service provider may offer the data hub platform as-a-Service and wholesale it to more than one retailer entity e.g. City A or City B or even businesses who want themselves to offer a data hub service; while the service provider hosts the data hub, the retailer entities operate it as their own, e.g. with their own brand, maybe bundling their own value-add services next to the data hub, facing their own customers e.g. data providers and data users. | • Platform Owner |

| Category | Capabilities | Business Roles |
|---|---|---|
| | **Whitelabeling Data Hub:** This is the simplest case of Data Hub platform-as-a-Service where a retailer entity e.g. a City buys the data hub service from a service provider (wholesaler), rebrands it with City logo etc, and operates it as is, off-the-self. | • Platform Owner |
| 2. Identity and Profile Management | **User authentication**: Proving user identity by different identity standards. | • Platform Owner |
| | **User authorization:** Determine user privileges or access levels related to API functionality. | • Platform Owner |
| | **User management:** define, collect and store user related information in secure way and compliant with privacy protection law. | • Platform Owner |
| 3.Analytics Support | **Data modeling and Service Orchestration (mash-ups of Digital Services):** Capability of generate a new dataset based on the combination and/or of one or more data sources. | • Value Add-er<br>• Platform Owner |
| | **Data Feed Analytics on Central Data Hub or on Edge Devices, such as on IoT gateways:** This is analytics facilities showing how data feeds perform e.g. monitoring feeds deliver data into the data hub as frequently as expected. This is a data hub embedded capability that can be provided either at the central data hub, running on the cloud and showing e.g. collective views of data or summary data, or at a mini version of data hub version running on Edge devices, e.g. IoT Gateways, where raw detailed sensor data is collected, analysed/filtered and then sent to central data hub in the cloud. | • Value Add-er<br>• Platform Owner |
| | **Analytics-as-a-Service for Central Data Hub or for Edge Devices:** Analytics capabilities customers/3rd parties could "purchase" as-a-Service to be provisioned for deployment on the central Data Hubs data centre or on Edge Devices. The key here is the ability for the City platform to support the deployment of app logic at premium compute platform where the data is collected, both at the central data hub and/or at the edge devices e.g. IoT gateways (assuming edge computing enablement of data hub) so that customers could do analytics where locally/nearby where the data is collected. | • Value Add-er<br>• Platform Owner |
| 4. Security/Privacy | **Data Privacy:** Data provider, during data feed onboarding, defines who is allowed to see and subscribe to feed (list of permitted access roles attached to the Data feeds → Federated Identity) | • Data Provider<br>• Platform Owner |
| | **Licenses/Commercial and Technical Agreements:** Data provider, during feed onboarding, defines Terms and Conditions governing the data and that consumers agree upon subscription and abide by upon use of data. | • Data Provider<br>• Platform Owner |
| | **White-listing of devices**, e.g. sensors and gateways, at the Data Hub, for secure registration and device management. | • Data Provider<br>• Platform Owner |
| | **Device Management:** marshalling ownership of devices and ensuring only authorised/signed app logic is allowed to execute on these devices. | • Data Provider<br>• Platform Owner |

| Category | Capabilities | Business Roles |
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| | **Data Service Qualification:** Ensure subscribers to data feeds attest to the privacy, access or other security rules or commercial commitments assigned by data providers. | • Data User<br>• Platform Owner |
| | **IoT security:** Management of device identifiers/security keys, encrypted communications between IoT sensors, gateways, Data Hub and customer apps. | • Data Provider<br>• Platform Owner |
| 5.High Availabilty and Escalability | **Data Hub as-a-service SLA Management**: inherent mechanisms for scalability and high availability of the data hub to serve demand of data providers onboarding feeds and sending data into the hub but also of applications/data subscribers getting data out of the hub. | • Platform Owner |
| | **Customer Apps SLAs**: support premium IT services next to the hub with mechanisms of scaling Customers Apps e.g. big data analytics, offered as-a-service and deployed at data hub data centre, next to where the data is hosted. | • Platform Owner |
| | **IoT Data Service SLA** | • Platform Owner |
| 6.Configuration & Activation Support | **Activation and configuration of new services:** Configure all the functions for a new data source and their characteristics. | • Data Provider<br>• Platform Owner |
| | **Actication and configuration of new costumers:** Deliver to the new costumers all data sources selected to be consumed. | • Data User<br>• Platform Owner |
| | **Data model correlation:** Provider will be able to correlate their datasets with standard data models to be provided as bundle. | • Data Provider<br>• Platform Owner<br>• Value Add-er |
| 7.Assurance & Traceability Support | **End-to-end SLA Management**: Layered SLA Management covering Data Provider, Data Hub Platform and Customer Apps. | • Data Provider<br>• Platform Owner |
| | **Application Priorities:** assigning priorities to Apps deployed at the premium Data Hub data centre, in order to manage application contention; e.g. only high priority Customer Apps can be deployed on the Data Hub's data centre, whilst already deployed lower priority apps will be migrated to 3rd party clouds. | • Data Provider<br>• Platform Owner |
| | **Services usage tracking**: All usage from ingestion and delivery must be logged. | • Platform Owner |
| | **SLA Analytics on Data Hub:** monitoring data feeds maintain SLA guarantees, | • Platform Owner |

| Category | Capabilities | Business Roles |
|---|---|---|
| | **SLA breach discovery**: Ability to notify SLA thresholds have been crossed and to identify the responsible entity for the breach of SLA (is it Data provider, is it network provider, is it Platform Service provider on data ingress point, is it Platform service provider on data egress point etc.). | • Platform Owner |
| | **Platform Digital Service SLA Management:** Ability to monitor and manage SLA guarantees of the platform functional components. For instance, scale up platform services or monitor their availability if demand increases, with inherent scaling/loadbalancing mechanisms. | • Platform Owner |
| | **Platform Digital Service Performance Management:** Ability to monitor the performance of the platform functional components (e.g. resource utilisation by each platform component), without necessarily having setup SLAs. | • Platform Owner |
| | **Data providers SLA Management:** Ability to monitor and manage Data Provider SLAs | • Data Provider<br>• Platform Owner |
| | **API Traffic management:** Ensure API performance by shaping traffic and caching mechanism:<br>• Caching<br>• Throttling (traffic limitation rules) | • Platform Owner |
| 8.Charging Support | **Customer charging:** Provide the charging to the customer with the periodicity defined. | • Data User<br>• Platform Owner |
| | **Data feed pricing:** Providers must define the pricing of their data sources and the usage modeling based on the class of services. | • Data Provider<br>• Platform Owner |
| | **Differential charging** per Data Feed Class of Service. | • Data Provider<br>• Platform Owner |
| | **SLA breach accounting**: calculating customer rebates, compensations and fines/punitive charges for the SLA breaching stakeholder/s (e.g. if data loss caused by Data Provider or by the Data Hub service provider in case of disrupted hub service operations). | • Data User<br>• Data Provider<br>• Platform Owner |
| | **Ecosystem SLA Accounting**: in case of SLA breach, customer rebates should involve collecting part of the already received revenue from all ecosystem partners involved in the service | • Data User<br>• Data Provider<br>• Platform Owner |
| 9.Invoicing Support | **Customer invoicing** | • Platform Owner |

| Category | Capabilities | Business Roles |
|---|---|---|
| 10.Payment Support | **Supplier payment**: provide the payment based on the consume. | • Data Provider<br>• Platform Owner |
| | **Revenue sharing:** Distribute incomes among stakeholders of a value chain. | • Data User<br>• Data Provider<br>• Platform Owner |
| 11.Catalog Lifecycle Management | **Data source registration for delivery:** The Data source providers register their data to be available at the platform. | • Data Provider |
| | **Resource monetization:** Provider can choose to offer their datasets no only for sale but also to join in a revenue sharing models with APP Developers and Service Providers. | • Data Provider |
| | **Data Feeds with Class of Service**: a data provider may define different classes of service for a data feed they aboard, based on the quality of the data the data feed supplies and charge differently per class. For instance, a car park data feed showing parking availability may provide 3 classes of service based on data resolution: bronze for 1 datapoint/24h, silver for 1 datapoint/hour, gold for 1datapoint/min. | • Data Provider |
| | **API Versioning:** API providers make versioning of API which let them to publish new version while giving time client application which using older version to align/upgrade application to use new API version | • Data Provider |
| | **Wholesaler Data Feeds/Applications/Services catalogues with pricing:** ability for providers to wholesale their offerings through the platform so that other entities bundle or re-sell as retailers to their customer segments (wholesaler-retailer model) | • Data Provider<br>• Platform Owner |
| | **Retailer Data Feeds/Applications/Services catalogues with pricing offering bundles mixing wholesaler offerings and own value-add offerings:** Ability for retailers to expose own catalogues of offerings, re-using/reselling/white-labeling wholesaler offerings they don't own, own value-add offerings or bundles of both, with their own charging and revenue split agreements . | • Service Provider<br>• Platform Owner |
| | **Edge Applications Catalogue:** Apps provisioned for deployment on edge devices e.g. IoT gateways. | • Service Provider |
| 12.On-boarding Support | **Provider on-boarding:** Data provider registration, validation and approval to publish their datasets at the platform. | • Data Provider |
| | **Ecosystem Enablement Platform:** enable and support ecosystem of partners to trade data and services onboarding new tenants to the platform as providers of data/apps/services they own playing the or resellers , i.e. entities which don't own but resell other providers offerings, maybe in bundles with own value-add services. | • Data Provider |
| | **Value Chain:** Support value chain management and to foster reutilization and innovation. | • Data Provider |

| Category | Capabilities | Business Roles |
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| 13. Federation Support | **Federated Data Hubs**: different city data hubs talk to each other, interoperate, exchange data supporting common data formats (e.g. HYPERCAT). | • Platform Aggregator |

*Table 8 TM Forum supporting capabilities*

# Annex 4 TM Forum Open API's

| TM Forum Open APIs |
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| **Account Management API**<br>Provides standardized mechanism for the management of billing and settlement accounts, as well as for financial accounting (account receivable) either in B2B or B2B2C contexts |
| **Activation and Configuration API**<br>The REST API for Activation and Configuration allows the user to retrieve, create, update, delete services and retrieve the monitor resource used to monitor the execution of asynchronous requests on a specific resource. Although all the examples given in the API specification are relative to Services, the same API can be used to Activate and Configure Services or Resources. |
| **Agreement Management API**<br>The Agreement API provides a standardized mechanism for managing agreements, especially in the context of partnerships between partners. |
| **Alarm Management API**<br>The Alarm Management API applies lessons that were learned in previous generations of similar APIs that were implemented in the Telecommunication industry, starting from ITU recommendations,, TM Forum OSS/J, MTOSI and TIP interfaces, NGMN alignment initiative between 3GPP and TM Forum interfaces, and the more recent ETSI work on requirements for NFV interfaces. |
| **Appointment API**<br>The appointment API provides a standardized mechanism to book an appointment with all the necessary appointment characteristics. The API allows searching of free slots based on parameters, as for example a party, then creating the appointment. The appointment has characteristics such as nature of appointment, place of appointment. |
| **Change Management API**<br>The Change Management API provides standard integration capabilities between external applications and Change Management Application. The API consists of a simple set of operations that interact with a Change Request in a consistent manner. |
| **Communication API**<br>Provides a capability to create and send communications, notifications, and instructions to Parties, Individuals, Organizations or Users. |
| **Customer Bill Management API**<br>This API allows operations to find and retrieve one or several customer bills (also called invoices) produced for a customer also allows operations to find and retrieve the details of applied customer billing rates presented on a customer bill. |
| **Customer Management API**<br>Provides a standardized mechanism for customer and customer account management, such as creation, update, retrieval, deletion and notification of events. |
| **Document Management API**<br>Provides the operations to synchronize documents and document versions across systems. It also provides operations for uploading documents by Users as well as for viewing of documents online |
| **Entity Catalog Management API**<br>The entity catalog is intended to provide any SID entity to consumers via a catalog, with its specification and policy providing governance over its content. The API provides management of the entity specifications and their associations thru CRUD operations. |
| **Federated Identity API**<br>The management of principals of any kind (persons, objects, …) and their access to resources in an open environment which can span across different enterprise boundaries. It relies on authentication, authorization and consent mechanisms to protect privacy with a simple and easy user experience. Different parties can provide identity services (operators, social networks, GSMA, …). |
| **Geographic Address Management API** |

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| Provides a standardized client interface to an Address management system. It allows looking for worldwide addresses. It can also be used to validate geographic address data, to be sure that it corresponds to a real geographic address. Finally, it can be used to look for a geographic address by: searching an area as a start (city, town ...), then zooming on the streets of this area, and finally listing all the street segments (numbers) in a street. |
| **Geographic Location Management API**<br>Provides the information of a geographic region of the entity (customer, equipment, address). |
| **Geographic Site Management API**<br>Covers the operations to manage (create, read, delete) sites that can be associated with a customer, account, service delivery or other entities. This API defines a Site as a convenience class that allows easy reference to places important to other entities, where a geographic place is an entity that can answer the question “where?” |
| **Loyalty Management API**<br>Supports the management of loyalty program specifications, loyalty program members, their associated products and loyalty accounts with loyalty balances |
| **Partnership Type Management API**<br>Standardized mechanisms for creating partnership types. It is one of the APIs involved in an onboarding process. Identifies a type of a partnership between parties, including the list of role types that are permitted (i.e Buyer, Seller, Developer). Role types may refer to agreement specifications to be signed by parties playing the role. The API allows the retrieval, creation, update, and deletion of partnership type and its owned sub-resources. |
| **Party Interaction Management API**<br>A User Interaction captures information about past interactions in order to re-use it in future ones. This allows agents to serve users better by knowing the steps they went through. It also allows customers to see better the actions they have performed and how they interacted with us. |
| **Party Management API**<br>Provides a standardized mechanism for party management such as creation, update, retrieval, deletion and notification of events.<br>Party can be an individual or an organization that has any kind of relationship with the enterprise. |
| **Party Role Management API**<br>A standardized mechanism for general party roles and includes operations such as creation, update, retrieval, deletion and notification of events. Notice that for the management of customers there is a specific Customer Management API.<br>Party Role management API manages the following data resources: PartyRole |
| **Payment Management API**<br>The Payments API provides the standardized client interface to Payment Systems for notifying about performed payments or refunds. Examples of Payment API originators (clients) include Web servers, mobile app servers, Contact center dashboards or retail store systems. |
| **Payment Methods API**<br>This API supports the frequently-used payment methods for the customer to choose and pay the usage, including voucher card, coupon, and money transfer. |
| **Performance Management API**<br>Provides a standardized mechanism for performance management such as the creation, partial or full update and retrieval of resources involved in performance management (Measurement Production Job, Measurement Collection Job, and Ad hoc Collection). It also allows notification of events related to performance. |
| **Performance Management Threshold API**<br>Provides a standardized mechanism for performance management such as creation, partial or full update and retrieval of the resources involved in performance management (Measurement Production Job, Measurement Collection Job, and Ad hoc Collection). It allows also notification of events related to performance |
| **Prepay Balance Management API**<br>REST API for Balance Management. It includes the model definition as well as all available operations for prepay balance management. Prepaid subscribers pay fees before using services. Therefore, the subscribers must have sufficient balances. Operators can provide multiple recharge channels for subscribers. Subscribers can pass credit between different subscriptions, therefore transferring the balance from one account to another. |
| **Privacy Management API** |

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| The Privacy management APIprovidesstandardizedmechanismfor privacy profile types, privacy profiles and privacy agreements such as creation, update, retrieval, deletion and notification of events.. |
| **Product Catalog Management API**<br>Provides a standardized solution for rapidly adding partners' products to an existing Catalog. It brings the capability for Service Providers to directly feed partners systems with the technical description of the products they propose to them. |
| **Product Inventory Management API**<br>Provides standardized mechanism for product inventory management such as creation, partial or full update and retrieval of the representation of a product in the inventory. It also allows the notification of events related to product lifecycle. |
| **Product Offering Qualification API**<br>Product Offering Qualification API is one of Pre-Ordering Management API Family. Product Offering Qualification API goal is to provide Product Offering commercial eligibility. |
| **Product Ordering API**<br>Provides a standardized mechanism for placing a product order with all of the necessary order parameters. The API consists of a simple set of operations that interact with CRM/Order negotiation systems in a consistent manner. A product order is created based on a product offering that is defined in a catalog. The product offering identifies the product or set of products that are available to a customer and includes characteristics such as pricing, product options and market. |
| **Promotion API**<br>Used to provide the additional discount, voucher, bonus or gift to the customer who meets the pre-defined criteria. Using promotion, the enterprise is able to attract the users and encourage more consumption, especially continuous purchases. Normally Promotion is not regarded as one type of product or product offering. It is often applied when the customer buys the product offerings with the price or amount surpassing the certain limit |
| **Quote Management API**<br>The Quote API is one of the Pre-Ordering Management APIs. The customer Quote API provides a standardized mechanism for placing a customer quote with all of the necessary quote parameters. |
| **Recommendation API**<br>Recommendation API is used to recommend offering quickly based on the history and real-time context of a customer. It is a real-time and personalized recommendation API. It is usually provided by e-commerce or BSS, CRM system in omni-channel. |
| **Resource Catalog Management API**<br>The Resource Catalog Management API REST specification allows the management of the entire lifecycle of the Resource Catalog elements and the consultation of resource catalog elements during several processes such as ordering process. |
| **Resource Function Activation and Configuration API**<br>This API introduces Resource Function which is used to represent a Network Service as well as a Network Function. The Network Service and Network Function class definitions and associations in TR244 (which, in turn, builds on concepts from the SID addenda on Logical Resource and Service) are utilized to define the Resource Function |
| **Resource Inventory Management API**<br>The intent of this API is to provide a consistent/standardized mechanism to query and manipulate the Resource inventory. |
| **Resource Ordering Management API**<br>The REST API for Resource Order Management. It includes the model definition as well as all available operations. Possible actions are creating, updating and retrieving Resource Orders (including filtering). A Resource Order API provides a standard mechanism for placing a Resource Order with all necessary order parameters. |
| **Resource Pool Management API**<br>Resource Pool management API provides a feature of resource reservation at pre-order phase. In order to reserve a physical product, logical product, and virtual product, the API uses the idea of a resource pool. |
| **Service Catalog API**<br>The Service Catalog Management API allows the management of the entire lifecycle of the service catalog |

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| elements. |
| **Service Inventory Management API**<br>The intent of this API is to provide a consistent/standardized mechanism to query and manipulate the Service inventory. |
| **Service Ordering Management API**<br>The REST API for Service Order Management provides a standardized mechanism for placing a service order with all of the necessary order parameters. It allows users to create, update & retrieve Service Orders and manages related notifications. |
| **Service Problem Management API (SPM)**<br>The SPM API is used to manage service problems. Service problems are generated based on the information declared by a partner or the event information notified from infrastructure providers. The event information includes alarm information, performance anomaly information, trouble ticket information, SLA violation, maintenance information and prediction information. |
| **Service Qualification API**<br>Service Qualification API is one of the Pre-Ordering Management APIs. Service Qualification API goal is to provide service availability at Customer location. |
| **Service Quality Management API**<br>Through this API, any Enterprise is able to access a Service Quality Management application and extract Service Level Specifications and associated Service Level Objectives (SLO) and their thresholds. |
| **Service Test Management API**<br>The Service Test API provides a standardized mechanism for placing a service test with all of the necessary test parameters. The API consists of a simple set of operations that interact with CRM/Service Management systems in a consistent manner. A service test is a procedure intended to check the quality, performance, or reliability of a service. |
| **Shipment Tracking API**<br>Shipment Tracking captures information about the current status of the shipment, the past checkpoints and the estimated arrival date. Via this API, tracking information can be retrieved by providing an order Id or the shipping company's tracking id. |
| **Shopping Cart API**<br>A standardized mechanism for the management of shopping carts. Including creation, update, retrieval, deletion and notification of an event. Shopping Cart entity is used for the temporary selection and reservation of product offerings in e-commerce and retail purchase. |
| **SLA Management API**<br>Provides a standardized interface for Service Level Agreement (SLA) life-cycle Management (SLA Negotiation, SLA configuration SLA Activation/enforcement, SLA Operations, SLA violation / consequence handling, SLA reporting) between a Customer and a Service Provider which provides offers (product with attached SLA in its catalogue) the customer can discover, browse, trigger and order. |
| **Trouble Ticket API**<br>Provides a standardized client interface to Trouble Ticket Management Systems for creating, tracking and managing trouble tickets among partners as a result of an issue or problem identified by a customer or another system. Examples of Trouble Ticket API clients include CRM applications, network management or fault management systems, or other trouble ticket management systems (e.g. B2B). |
| **Usage Consumption Management API**<br>This API should allow viewing in real-time the balance of the various buckets (SMS, Voice, Data for example) that a user consumes with each of his devices and the usages done out of the bucket. A usage report retrieves the data related to these balances. This API should also allow performing a direct top-up on the balance of a prepaid bucket with voucher references or with a given credit value after a payment done by a credit card or with a credit value transfer. |
| **Usage Management API**<br>Provides standardized mechanism for usage management such as creation, update, retrieval, import and export of a collection of usages. The API manages both rated and non-rated usage. For example, it allows a service provider to 1) retrieve usage generated by a partner service platform in order to rate it and 2) to provide rated usage to a partner for consumption follow up purposes. |

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| **User Roles & Permissions API**<br>A user role is defined as the entity that defines a set of privileges covering various functions and/or manageable assets. When a user is assigned a given role then it is actually allocated all the privileges defined for that role type and the corresponding permissions are created for that user. |

*Table 9 TM Forum Open API's*