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Context Information Management (CIM); Use Cases (UC)

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) cross-cutting Context Information Management (CIM).

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1 Scope

The present document discusses the concepts which are foundational for Cross-Cutting Context Information Management (C3IM) and their application to a selection of Use Cases from the domains of Smart Cities, Smart Agrifood and Smart Industry. These areas of application, together with the general area of Internet of Things (IoT) technology and services, are expected to especially benefit from usage of cross-cutting (cross domain) context information, and from a set of specifications for the APIs supporting C3IM.

The present document covers the following:

- A definition of terms relevant to cross-cutting Context Information Management (C3IM).
- An introduction to the notions of C3IM and the potential role of C3IM in enabling services in cross-cutting inter-domain areas, for example Smart Cities, Smart Agrifood, and Smart Industry.
- A motivation for this project's key goal, i.e. defining an API for C3IM.
- A reference diagram illustrating possible architectures and functional entities involved in facilitating C3IM.
- A set of high level Use Cases which can potentially be supported using a C3IM system.
- A subset of detailed Use Cases (scenarios) illustrating potential information flows among functional entities.
- A summary of requirements extracted from the Use Case analysis.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] INSPIRE Data Specifications Drafting Team, 2008-03-18: "Deliverable D2.3: Definition of Annex Themes and Scope".

NOTE: Available at http://inspire.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.3_Definition_of_Annex_Themes_and_scope_v3.0.pdf.

[i.2] INSPIRE: "European Data Portal -Training & Library - Use Cases".

NOTE: Available at https://www.europeandataportal.eu/en/training-library/library/training-materials.

[i.3] European Data Portal: "Re-using Open Data: A study on companies transforming Open Data into economic and societal value", CapGemini, 20170117.

NOTE: Available at https://www.europeandataportal.eu/sites/default/files/re-using_open_data.pdf.

[i.4] "DIGITALEUROPE's views on the Artificial Intelligence, Machine Learning and Robotics", Brussels, 10 May 2017 Published 20170510.

NOTE: Available at http://www.portugalglobal.pt/PT/Acoes/missoes/Documents/2017/belgica-2nd-innovation-sessions-digital-europe.pdf.

[i.5] Pohl, Klaus: "Requirements engineering: fundamentals, principles, and techniques". Springer Publishing Company, Incorporated, 2010.

[i.6] Library of Congress of USA: "PREMIS Data Dictionary for Preservation Metadata version 3.0".

NOTE: Available at http://www.loc.gov/standards/premis/v3/premis-3-0-datadictionary-only.pdf.

[i.7] W3C, PROV Model Primer. Working Group Note 30 April 2013.

NOTE: Available at http://www.w3.org/TR/2013/NOTE-prov-primer-20130430.

[i.8] ITS International: "Substantial savings from smarter street lighting", first published January 2015.

NOTE: Available at http://www.itsinternational.com/sections/general/features/substantial-savings-from-smarter-street-lighting/.

[i.9] ETSI GS CIM 004 (V1.1.1) (04-2018): "Context Information Management (CIM); Application Programming Interface (API)".

3 Definitions and abbreviations

3.1 Definitions

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

agent: system, software program or firmware that is a producer, consumer or manipulator of data in a use case

NOTE: That in some use cases, an agent may act on behalf of a human or legal stakeholder.

context: set of entities with which an entity has defined relationships, together with the categories (classes) and properties of these entities, their relationships and their properties

context information: informational representation of a context

cross-cutting context information: context information that spans multiple distinct application domains

(Cross Cutting) Context Information Management (C3IM): following services provided by a platform: context information registry, discovery, publication, mediation, modification or notification, and more generally mediation between context information sources and context information users

NOTE: The acronym C3IM is used only in the present document as a shortcut for, cross cutting context information management, rather than CIM to avoid confusion with acronyms uses by other SDOs (e.g. ISO/IEC Common Information Model).

entity: something existing in the real world such as a person, a place such as a building or street corner, an object such as a car or tree or refrigerator or any equipment or sensor, a document such as a book or legal document, which can be represented in a context information management platform

NOTE: This is different from the sense in which the oneM2M specification uses the word "entity".

information model: set of types and associated constraints that formally define the classes(categories) used for context information representation

NOTE: The information model constrains the specific representation of the structure, manipulation and integrity aspects of the data stored in data management systems such as graph databases, whereby generic cross-domain and specific domain-dependent terminologies/taxonomies are used for the information elements and their instantiations.

property: description instance which associates a literal characteristic (e.g. a value in a common data type). to either an Entity, a Relationship or another Property

relationship: description of a directed link between a subject which is either an Entity, a Property, or another Relationship on the one hand, and an object, which is an Entity, on the other hand; for example "isAdjacent to", "isContainedIn", "is ASubSystemOf", "isOwnedby", "isCreatedBy"

stakeholder: person, business or other legal entity who is involved in a service or process of a use case

situation: set of entities and services, and their dynamic states, interacting within a specific geo-temporal range

target domain: set of business activities (e.g. automobile traffic flow planning, energy distribution, etc.) within which traditional use cases are defined

NOTE: The entities of a target domain may be shared with others (e.g. streets as city entities are shared between traffic management and lighting management) and this is precisely where cross-cutting context information comes into play.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ADSL Asymmetric Digital Subscriber Line
AI Artificial Intelligence
AIOTI Alliance for the Internet of Things Innovation
ALPR Automatic License Plate Recognition
API Application Programming Interface
ATM Automated Teller Machine
CAL Climate Associates Limited
EC European Commission
EGM Easy Global Market
EU European Union
EV Electric Vehicle
GHG Green House Gas
GPS Global Positioning System
HTTP Hypertext Transfer Protocol
HTTPS Hypertext Transfer Protocol Secure
ICD Implantable Cardioverter-Defibrillator
IoT Internet of Things
ISG Industry Specification Group
ISO International Organization for Standardization
KPI Key Performance Indicator
NEC Nippon Electric Company
NGSI Next Generation Service Interfaces
OWL Ontology Web Language
RDF Resource Description Format
SMS Short Message Service
UI User Interface

4 Introduction

4.1 Introduction to Context Information Management

As stated in the scope, the present document concerns the application of cross-cutting contextual information management to a selection of Use Cases from the domains of Smart Cities, Smart Agrifood and Smart Industry. These applications are expected to especially benefit from cross-cutting context information and from a set of specifications for the APIs supporting C3IM.

Cross-cutting Context Information Management (C3IM) is provided by a C3IM platform. A C3IM platform collects data from IoT devices, lower-level platforms managing such devices, crowdsourced devices, databases and other sources, and provides as consolidated context information to applications via an API (defined in later documents as NGSI-LD). The C3IM platform enables use-cases which link together disparate but related information. It is thought that IoT services will be enriched when applications have access to a full set of context information, as defined in clause 3. A C3IM system potentially enriches services by bringing together information from a wider set of service-relevant sources than would otherwise be available to a traditional vertically integrated IoT application.

This is illustrated in figure 4.1-1. In the first figure, an IoT information source such as a sensor provides data to an application. As an example, an IoT-enabled fitness tracker device reports heart rate and step counts to a user via a cloud-based "runner fitness" service. The user is simply able to access current values and past statistics for these measures. For best results and widest interoperability, the transfer of information from the sensor to the cloud application needs to be accompanied by the semantics and context of the information (i.e. the numbers sent are "heart rate", not "blood pressure" or some other measure).

The simple example makes clear that the protocol to exchange data should contain (or reference) all context information needed to correctly interpret that data for a given service (the cloud application) and that the protocol should be designed to function between widely different kinds of information sources and information "consumers". For widest interoperability, nothing should be assumed.

Figure 4.1-1: Exchange of (context) information between a source and an application

In figure 4.1-2, the first information source is supplemented by additional contextually relevant information from a variety of databases or other sources. The Application has access to a wider set of information and can provide a richer service. To continue the example, an enhanced runner fitness service uses GPS location (from the user's phone sensor), road inclination (from a municipal database), weather information (from a national government service web-API) and traffic conditions on the road (from a web API of a popular map application). These are tied together by the application. The user sees suggested running routes based upon his/her goals and local conditions, can track his/her progress and speed, and sees graphs of heart rate against estimated calorie burn, speed, or road inclination.

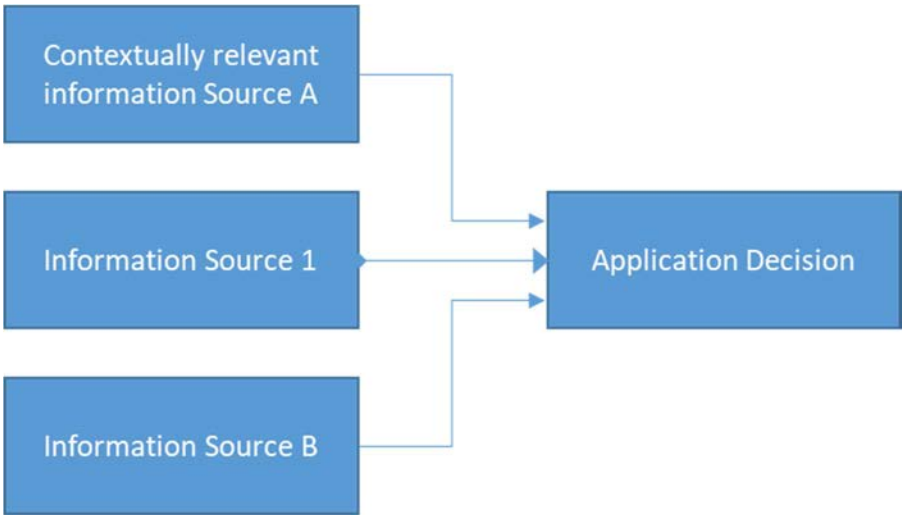

Figure 4.1-2: Merging of several contextual information sources to enhance an application

Access to relevant context information from multiple target domains enables "cross-cutting" applications to present a richer service to the user. To summarize, a C3IM system may utilize information of the following characteristics:

- information about or from one or more entities;
- static or dynamic information;
- information from database including open data;

- different sources leading to similar information (for example, in some cases temperature may be reported by a user, in other cases temperature may be reported from a sensor).

The C3IM system is expected to make it easier for applications to access this heterogeneous information by standardizing the APIs between applications, data aggregation platforms, and entities.

4.2 Information Sources

The purpose of the present document is to help clarify interoperability requirements for transmission and management of information between different information sources which have been developed under different sets of assumptions and definitions, particularly for:

a) various kinds of Internet-of-Things sensor/actuator frameworks;

b) various kinds of databases created and maintained for processes within municipalities and governments;

c) various kinds of internet/mobile applications promoting interaction of end users with the digital world, etc.

Everyone talks about the new digital society, digital transformation or fourth industrial revolution, etc. but building it will require unprecedented trading (not just "sharing") of information in forms which remain correctly interterpretable at all stages.

It is assumed in the present document that there are actually five broad sources of information about the real world, made available in the digital world and managed within a context information management platform:

a) **IoT Platforms:** they mediate raw data originating mostly from various sensors within the target environment. (e.g. a Smart City, an industrial compound, etc.). This mediation takes place through a two-sided platform that acquires, aggregates, references and maintains this data as consolidated information in order to make it available to applications or higher-level platforms operating within this environment.

b) **Managed Database Platforms:** containing aggregated, consolidated, filtered, etc. information, by stakeholders such as government agencies, commercial businesses, or subordinate lower-level database platforms, network servers, gateways, or third-party information services. Typical examples are statistics for crime, for traffic flow, for environmental pollution, for delays in scheduled public transport, or catalogues of information such as catalogues of products, of government requests for tender, of properties available for sale.

c) **Application Data Platforms:** applications delivering extremely varied kinds of data, usually from a multitude of end users. The kinds of data could be e.g. user-generated gps tracks of cars (input into a traffic flow database), user-identified locations of dangerous damage to streets (input into a municipal map for roadworks planning), etc.

NOTE: The difference to a Managed Database Platform is that the application services are not strictly filtered/managed by a uniform registration process and/or a single organization, and include many single-user sources of information, often with short validity period e.g. the time immediately after sending a SMS.

d) **Data Analytic Platforms:** consist of context information which has been derived from any and all other available information, including models and simulations, by specialized software. The provenance of such information needs to be very carefully tracked and taken into account when reaching conclusions (by humans or machines).

e) **Usage Data:** based upon roles and permissions for (re)use of the above data sources, accounting and provenance data accompanying access, logical extrapolations from all such data and *usages of that data.* Judging by commercial efforts to develop artificial intelligence platforms, commercial platforms for information retrieval and commercial platforms for sharing of information between friends and friends-of-friends, the set of networks of users of specific types of information will itself be a factor in the digital environment (and economy) for all users, in particular for services involving advertising and/or billing.

4.3 Motivation for developing a Context Information Management System

It is the goal of ETSI ISG CIM to facilitate consolidation and re-use of the different kinds of data and information sources, and multiple instances of any of the sources, into a federative platform. Cross-Cutting Contextual Information Management corresponds to the cross-fertilization and federated use of multiple sources of information, such that the original meaning and context (definition and provenance) of such information is not lost during transfer.

The term "context information" has a broad definition within the present document, including in principle all additional information about a bare recorded "fact" which would be needed to interpret that fact unambiguously under all circumstances. Usually, however, the term "context information" is pragmatically used in the sense of "additional information which explains the definition of the type of observation and the conditions affecting its observed value within a specific (set of) situation". This is more practical but also more limited and leads to situations where "one man's definition of context is another man's definition of irrelevant blather".

What is the meaning of the term "cross cutting" in connection with context information? The term emphasizes that information from one context may be highly useful in another, particularly if (a) the two contexts belong to disparate target domains, but also for (b) two very similar or even identical contexts where the information modelling of the entities, services or roles has developed in a non-identical way. An example of (a) is exchange of information between a bus timetable planning system and a weather prediction system. An example of (b) is exchange of information between police departments in two adjacent cities in different nations (example Saarbrueken).

The emphasis on "independent target domains" in C3IM clarifies the term "cross-cutting", indicating that information is combined from sources which may have only partial overlap - or even conflict - of explicit or implicit information models. These conflicts may occur even within the same target domain (e.g. the smart home) if description of data (meaning, provenance, etc.) is ambiguous, changes over time, or changes according to the person/system responsible for the sourcing of information.

It should be emphasized that the meaning of "context" nowadays (and in the present document) has changed markedly from the formerly prevailing definition of context originating from the "first wave" of context-awareness that dominated research in the years 2000-2010, as taken up within the broader "ambient intelligence" research agenda at that time. Context was then defined in a mostly end-user-centric way, which implicitly assumed that there existed a primary information source called "content" (typically audiovisual media or multimedia interpersonal communication), and "context" was defined relative to this user-centric content as anything that provided ancillary information. Typically, the aim was to enable the user to better "consume" the content, or in general to improve the content with regards to various criteria.

That end-user-centric view and the context vs content distinction have no relevance in the broader domain of IoT platforms and Database Platforms that is targeted here, because what is primary content for one application is context to another, and the C3IM platform is intended to serve all applications irrespective of the primary content they request. The C3IM platform should thus manage information at a level that makes it possible to consolidate all sources of potential content and context information jointly.

The above explanation motivates the key criterion in selecting use cases for the present document: they should demonstrate the benefits of mixing information from different sources, each of which corresponds to a source of "primary" information dedicated to one application, showing that jointly the combination can be richer, more reliable or more adaptable.

The barriers for successful cross-cutting context information management are still so high, that a CapGemini survey [i.3] published in 2017 of companies active in the field found that across 14 categories the correlation matrix of re-use of open data from two independent domains was only above 50 % for four pairs of categories:

a) Transport with Cities.

b) Environment with Cities.

c) Population and Society with Cities.

d) Population and Society with Environment.

Some examples of cross-domain use cases which require access to information from different domains, that is normally held separate, are:

- Smart Lighting and Smart Parking so that lighting is only provided when car parking is booked and used in order to save energy.
- Smart Buildings and Smart Mobility to ensure that power is available to charge electric vehicles when required (in order to reduce GHG emissions and improve air quality in a neighbourhood).
- Smart Parking and e-Health to ensure that parking spaces are available for health professionals when required.
- Smart Energy and Smart Buildings to improve the buildings environment and energy management based on information collected on the indoor and outdoor environment including energy consumption and production.
- E-Health and Smart Appliances to monitor appliances to check if they have been 'left on' by the user (detection of abnormal events).

Various H2020 research projects provide different practical examples of the above types:

- Management of Networked IoT Wearables - Very Large Scale Demonstration of Cultural and Security Applications - www.monica-project.eu.
- ACTivating InnoVative IoT smart living environments for AGEing well - www.activageproject.eu.
- AUTOmated driving Progressed by Internet of Things - www.autopilot-project.eu.
- Internet of Food and Farm 2020 - www.iof2020.eu.
- Delivering an IoT enabled Digital Single Market for Europe and Beyond - www.synchronicity-iot.eu.
- User Engagement for Large Scale Pilots in the Internet of Things - www.u4iot.eu.
- CRoss FErtilisation through AlignmenT, Synchronization and Exchanges for IoT - www.create-iot.eu.
- VICINITY - www.vicinity2020.eu.
- Wise-IoT - http://wise-iot.eu.

5 Methodology

5.1 Approach to Documenting Use Cases

5.1.1 Purpose

The main purposes of writing down C3IM Use Cases document are:

- to provide examples of services which require the use of a C3IM platform;
- to understand the requirements for an appropriate API and Information Model.

The list of Use Cases presented is not meant to be exhaustive, but to provide example services in the Smart City and other topic areas.

5.1.2 Assumptions about a C3IM Architecture

In documenting Use Cases, several assumptions regarding the C3IM Architecture are made:

- It is assumed that C3IM platforms have an appropriateAPI through which they can query other systems, provide notifications, and receive responses to queries. For example, a ParkingManagementSystem could query a TrafficManagementSystem about road occupancy at a particular egress gate. No particular format of these transactions is assumed or specified in the present document, however detailed specifications are provided in the API document [i.9].
- It is assumed that means are available for C3IM platforms to discover, register, and report existence of entities and relationships within and across several instances of platforms. Distributed C3IM platform instances need also to be able to reconcile the identity of entities referenced in the different systems. The mechanisms to do so are not described in the present document.
- An Information Model specifying the classes of entities, relationships and properties is assumed to be used by a C3IM system. An Instance Graph showing properties and relevant contextual relationships of specific entities is shown for each Use Case. The methods by which the Information Model is created are not discussed in the present document.

5.1.3 Use Case Sections

Each Use Case description includes the following sections.

Introduction and Assumptions

An overview of the Use Case, important assumptions and links to external references if applicable, are described.

Information Flow Diagram

A coarse-grain Information Flow Diagram depicts for each Use Case the usage scenarios and types of information exchanged among the Agents of the involved in the Use Case, as well as some of the external entities associated with each use case as either data sources (typically sensors or input user interfaces) or data sinks (typically actuators or output user interfaces).

Agents are depicted as ovals with a dotted outline. Entities are represented by solid rectangles.

In this diagram, the Agents are presumed to communicate through an appropriateAPI (called NGSI-LD in later documents) to a C3IM platform. Through this NGSI-LD API, Agents provide context information of Entities associated with them, or receive context information about Entities associated with other Agents, or do both. The C3IM platform is represented as a cylinder connected to the Agents. No assumption is made about the architecture of the C3IM platform, for example if it is centralized or distributed.

Figure 5.1.3-1 shows the relative roles of a C3IM platform, a data consuming Agent and a data providing Agent.

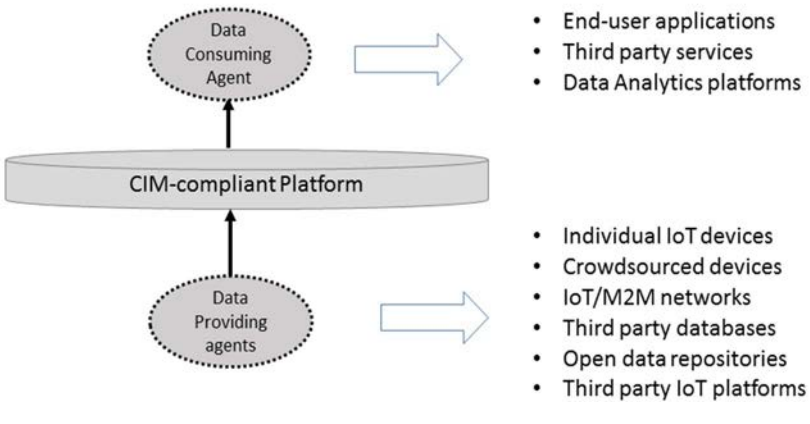

Figure 5.1.3-1: Roles in a C3IM platform, for a data consuming Agent and a data providing Agent

Stakeholders

The Stakeholders and a description of their assumed role and/or interest in the Use Case are provided. Examples of Stakeholders are Parking Manager and Smart City Planning Authority.

Agents and Data Source/Sink Entities

The Agents (which may be systems) and associated entities which are data sources and data sinks, together with a description of data handling by the agents within the Use Case, are presented in a table.

Examples of Agents are ParkingManagementSystem and TrafficManagementSystem. Examples of data source/sink entities are devices such as parking gate actuators, road sensors and cameras.

Scenarios

Each Use Case involves one or more Scenarios, which each describe a particular service and information flow within the Use Case. Scenarios do not necessarily involve every Agent or entity shown in the Use Case.

Data exchanges between pairs of Agents that are required to achieve the Scenario are shown in tabular format.

Entities Instance Graph

For each Use Case, an Instance Graph depicts the specific concrete entities and context relationships involved in the Use Case Scenarios. The Instance Graph provides a pictorial view of the Information Model used by the C3IM systems. It shows contextual relationships both within and among systems. The first such Instance Graph is figure 7.1.6-1.

In contrast, the Information Flow Diagram does not show these detailed context relationships, but rather shows queries and responses between Agents using an appropriate API.

The information elements of this Instance Graph are as follows:

- Entities associated with a particular software Agent in the Use Case, as shown in the Information Flow Diagram, are enclosed within a dashed oval.
- Entities which are enclosed within two or more dashed ovals are visible to each corresponding Agent, but are normally supposed to be controlled by only one of the Agents.
- Entities are represented by solid rectangles with incoming and/or outgoing arcs:
  - An outgoing arc indicates that an Entity is the subject of a relationship or property.
  - An incoming arc indicates that an Entity is the object of a relationship.
  - Connected devices are a special type of Entity shown shaded.
- Relationships are represented by a diamond, which should be considered as a label on the arc linking a subject entity and an object entity:
  - Verbs are used to describe relationships. The following verbs are used in the examples:
    - "contains".
    - "isActuatorFor".
    - "IsConnectedTo" - indicating a physical or logical interconnection, depending on domain. The relationship is bidirectional although the arrow may be shown as single ended.
    - "IsAdjacentTo" - indicating physical proximity. The relationship is bidirectional although the arrow may be shown as single ended.
    - IsSensorFor.
    - hasOpening.

- Properties are represented by ovals, which should be considered as a label on the arc linking a subject (entity) and an object (value):
  - An incoming arc may be omitted if the oval is drawn directly adjacent to the corresponding Entity.
- Values are indicated by a hexagon with an incoming arc coming from the corresponding Property:
  - An incoming arc may be omitted if the hexagon is drawn directly adjacent to the corresponding Property.

5.2 Composing Use Cases

The present document distinguishes in the use cases between two kinds of "participants", the Agents which are directly involved in exchanging (context) information and are often software applications or user-controlled Apps, and the Stakeholders which are the human users and legal entities either providing the service, using the service, or benefiting (sometimes being discommoded by!) the service.

Strict practitioners of use-case based requirements engineering [i.5] will recognize our use of the term Agent to be similar to the definition of "Secondary Actor".

However, it was considered overkill to always use the word "Secondary". Moreover, our use of the term Stakeholder is broader than the commonly used term "Primary Actor" and was deliberately chosen to emphasize that in SmartCity services - and public planning in general - the community which influences choice, use, abuse and critique of services is usually very large.

The next clauses will look at the set of stakeholders, agents and the set of data types commonly encountered.

5.3 Stakeholders

The kinds of Stakeholders in Smart City use cases are numerous: the list below is not exhaustive. Also shown are examples of the data which (might be) available from each Stakeholder via its agents. Of course, each agent could also have the role of consumer of data.

Examples of Stakeholders in Smart City Use Cases:

- Citizens.
- Telecom Providers.
- Waste Management Authority.
- Vehicle Traffic Management.
- Public Lighting.
- Education Authorities.
- Commerce B2B and B2C.
- Food Producers.
- Manufacturers.
- Municipal Public Service Providers.
- Government Environmental Protection Agencies.
- Utilities (Water, Heating, Power).

5.4 Example Entity types

5.4.0 Introduction

Each stakeholder or agent in a (Smart City, SmartAgri or SmartIndustry) use case may (desire to) publish or consume context information involving a wide range of entity types, and combinations thereof. It should be possible to exchange all such data and context information using an agreed protocol. The purpose of this clause is simply to illustrate the very wide range of entity types and entity-property types which may need to be exchanged, without attempting any exhaustive list.

Pieces of data that would correspond to *properties* of entities are given in italics in clause 5.4.1.

5.4.1 Geospatial examples

Just for geographical data, the types of information published in open data formats by European government entities is exemplified by the themes in the INSPIRE programme. The list below is adapted from a small subset of table 1 in [i.1]. The majority of this data is relevant to Smart City, Smart AgriFood or Smart Industry use cases:

- **Geographical units:**
  - Coordinates in geographical reference systems.
  - Geographical names.
  - Air and atmospheric conditions.
  - Climate type.
- **Administrative units:**
  - Official administrative units.
  - Government management zones.
  - Blocks, census and statistical districts.
  - Civil security units.
  - Environment management & reporting units.
  - Postal code areas.
- **Buildings:**
  - Properties (e.g. agricultural estates, industrial compounds, etc.).
  - Buildings.
  - Houses.
- **Transport networks:**
  - Transport vehicles.
- **Utilities networks and facilities:**
  - Transmission lines and pipelines.
  - Environmental protection facilities.
  - Agricultural facilities.
  - Trade and service facilities.

- **Society and population units:**
  - Urban and rural settlement.
  - Cultural heritage.
  - Natural amenities.
- **Water bodies, ocean & seas:**
  - Surface water bodies.
  - Hydrography networks.
  - Water catchments.
  - Sea regions.
- **Biota/biodiversity:**
  - Bio-geographical regions.
  - Habitats and biotopes.
  - Areas of intensive exploitation.

5.4.2 Provenance Data examples

A very different type of data is related to the C3IM system itself: provenance and auditing information necessary to monitor and check the proper operation of the whole system, which may include accounting operations and will certainly include traceability in case of liability.

The organization DigitalEurope noted [i.4] (in the case of Artificial Intelligence systems, but it is equally relevant to C3IM systems) that:

"To reap the societal benefits of AI systems, we as members of society first need to trust them. The right level of trust will be earned through repeated experience, in the same way we learn to trust that an ATM will register a deposit, or that a road vehicle will stop when the brake is applied. Put simply, we trust things that behave as we expect them to. Trust is built upon accountability."

The USA Library of Congress has coordinated an interdepartmental effort over many years to define an information model that defines for any kind of archiving system (which of course could include a C3IM system) the entities that are described (Objects, Events, Agents and Rights), the properties of those entities (semantic units), and relationships between them. This model is called PREMIS and has a defined representation in OWL ontology and RDF encoding which involves over 80 different characteristics [i.6]. The PREMIS information model is a super-set of the W3C provenance ontology [i.7].

6 Simplified functional reference architecture

A conceptual overview of a C3IM system is shown below, illustrating five different types of information sources to be mediated by the platform.

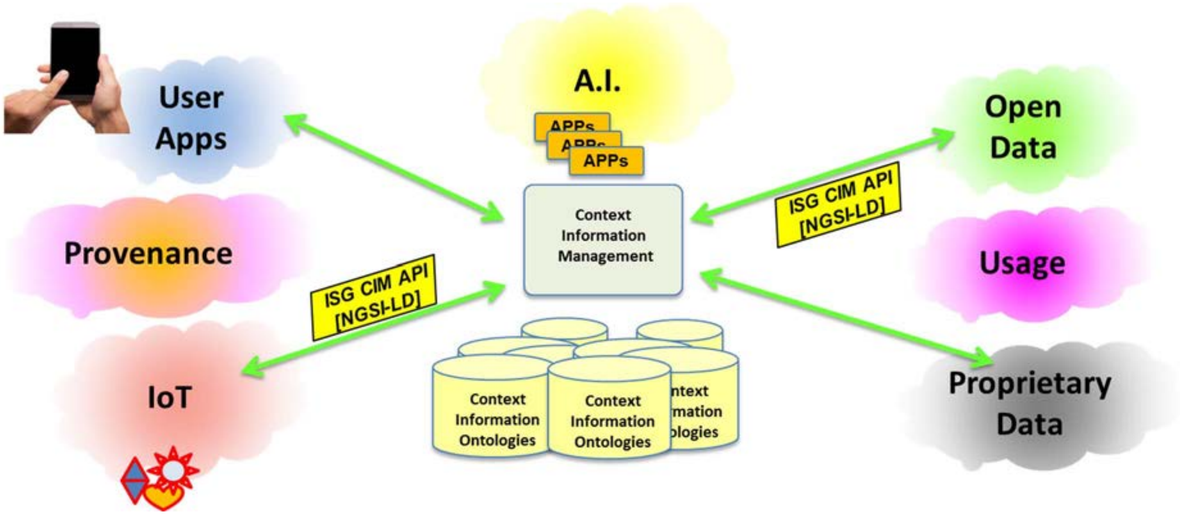

Figure 6-1: Conceptual overview of a C3IM System, showing exchange of data between IoT Platforms, Curated Databases (Open Data or Proprietary) and Application Data Platforms

7 Smart City Cross-cutting Use Cases

7.1 Use Case 1 Sharing information between parking management systems and traffic management applications

7.1.1 Use Case 1 Introduction and Assumptions

Smart Parking applications provide information and services to parking facility managers and to drivers searching for parking spots (the latter a cause of considerable congestion in city streets as well as time lost).

A goal is to make it as easy as possible for drivers to find and get to an acceptable parking space, minimizing the impact of drivers looking for parking on congestion/balancing traffic and parking across an area.

Compared to existing parking applications already available in some locations, C3IM-assisted parking applications will enable the following by accessing information from a variety of sources ("cross-cutting"):

- Drivers can find parking according to all available parameters near a specified destination.
- Drivers can receive a unified view of all available parking spaces in an area (across multiple providers).
- Parking facility managers can notify drivers of available parking spots, analyse "history" of parking patterns and statistics, and provide advanced guidance to drivers planning in future on using their facility. Such services will help retain and attract customers.
- Parking facility managers can analyse typical stay times to optimize restrictions on limited-time spaces e.g. make sure short stay spaces at railway station are used for pick-up/drop-off of passengers (maximize availability for this) and are not attractive for others.
- Smart city administrators and planning authorities can decrease pollution, provide service to their citizens and visitors, and improve the reputation of their city.
- Smart city administrators and planning authorities can access occupancy data over time across all parking spaces to support planning activities (e.g. identify whether/where additional parking capacity is required, maximizing use of existing parking spaces to avoid building new capacity.

The following assumptions are made in this Use Case:

- As in the Milton Keynes smart project, a driver has multiple options for parking (different car parks, parking zones, etc.) and wants to find one that is reasonably close to some location and that meets his requirements for length of stay, price and other criteria. Exactly which car park may not matter; time to reach the car park/congestion encountered may be more important but can generally not be considered as the driver doesn't have sufficient information.
- Existing traffic management systems are typically managed independently from the parking management systems.
- Sharing information amongst traffic and parking management systems will help drivers quickly find parking and decrease congestion on streets.
- The information should also be made available to third parties.

7.1.2 Use Case 1 Information Flow Diagram

Figure 7.1.2-1 shows the agents interacting with a C3IM-compliant platform and the corresponding C3IM-compliant information flows that support this use case. The data source/sink entities (sensors, actuators) associated with each agent are also shown.

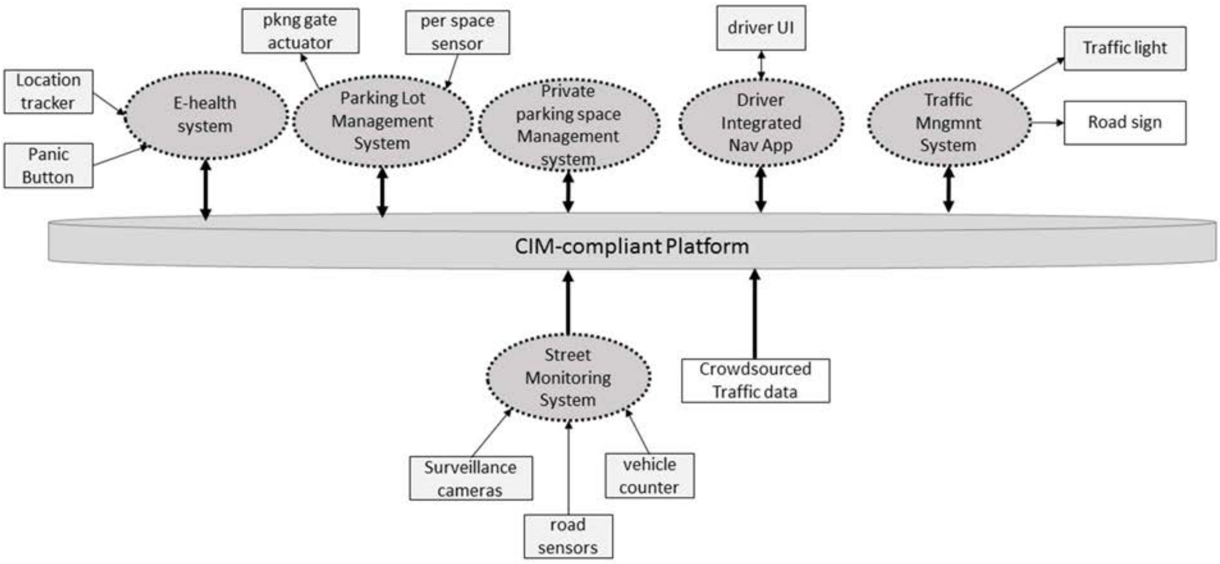

Figure 7.1.2-1: Context Information Exchange between Agents and Data Sources/Actuators in Parking Management Application

The following information types should likely be described as responses to queries within one of the scenarios:

- Information on special properties of parking spaces (e.g. EV charging, disabled, parent/child, residents only, inside/outside/on-street/etc.), and their space.
- Pricing information for available spaces (based on time of day/length of stay, etc.).

7.1.3 Use Case 1 Stakeholders

The Smart Parking Stakeholders are shown in table 7.1.3-1.

Table 7.1.3-1 Use Case 1 Stakeholders

Stakeholder	Role in Use Case
Local Smart City planning authorities	The government of a Smart City seeks to reduce and manage traffic flow and reduce pollution. It deploys infrastructure such as **TrafficManagementSystem** and **StreetMonitoringSystem** to support drivers and parking facility mangers.
Drivers entering city looking for parking space	Drivers needs information about available parking spaces. They wants to minimize unnecessary driving by quickly locating appropriate parking space. To do so, they makes use of a **DriverNavigationApplication**.
Parking Facility Manager/Owner(s)	Parking Facility Managers seek to attract customers by increasing visibility and advertising available spots. The Parking Facilities range in size up to a large commercial parking house. Facility Managers differentiate their parking service by giving information to drivers about the parking lot, price, space availability, and current traffic conditions. They need access to current demand for parking spots by category. They make use of **ParkingManagerApplication.**
Private parking space owner	Individual owners of parking spaces may make them available for short term, just as a public for-pay parking place in a commercial parking structure or parking lot. This could be supported by a service similar to "AirBnB" for parking spaces.
E-health system operator	An operator of an E-health system which provides in-home monitoring and support services may need to dispatch care workers to residences, and to arrange parking for the care workers as they are dispatched.

7.1.4 Use Case 1 Agents and Data Source/Sink Entities

In table 7.1.4-1, a Data Source is an entity such as sensor which provides data to an agent, and a Data Sink is an entity such as an actuator which is controlled by an agent. (The association of Agent and Entity is not meant to be restrictive, in other words an Entity could provide data from more than one Agent.)

Table 7.1.4-1: Use Case 1 Agents and Data Source/Sink Entities

Agent	Agent Description/Data Handling	Data Source/Sink Entity
TrafficManagementSystem	A system operated by the Smart City to help manage traffic flow. It integrates information from sources street monitoring system and the availability of parking places from different providers, using an appropriate API.	
ParkingManagementSystem	A system used by the Parking Facility Manager to assess current conditions and to manage the IoT enabled assets of the **SmartParkingBuilding**. It collates information from parking spot occupancy sensors. It controls the parking gates. provides information to a **DriverNavigationApplication** via an appropriate API.	**Per-space sensor** (e.g. fixed to the road surface) measuring vehicle presence. **Camera** to monitor occupancy of groups of spaces (video analytics to detect presence of a vehicle). **ParkingGateActuator** for parking gate control. **VehicleCounter** (e.g. inductive loops/cameras) on entry/exit of a parking zone.
DriverNavigationApplication	An application used by drivers to find available parking spots and optimal routes to these spots taking into account real-time information about street congestion. It accesses information from all **ParkingManagementSystems** and individual renters of parking spaces via an appropriate API, as well as information about road congestion.	UI hosted either on smartphone or car Navigation interface.

Agent	Agent Description/Data Handling	Data Source/Sink Entity
StreetMonitoringSystem	A system providing information through a C3IM-compliant platform, that may be used by the **ParkingManagementSystem** to estimate road occupancy at the egress gates of the parking garage. and by **TrafficManagementSystem** to reroute traffic along less congested routes. It combines information from among other types of sensors, video cameras and inductive loop sensors.	**Sensor** installed in the roadway to indicate road occupancy. **Traffic flow monitor**/**congestion detector.**
Private Parking Space Management System	Aggregates data from individual parking space owners who wish to make them available for short term rental.	**Sensors** of parking space occupancy. **Barrier/Bollard** to open up parking place.
E-health System	The E-Health System uses a variety of in-home devices to track activity, wellness, and location of persons using an Assisted Living Service. GPS location is used to track location of patients with dementia, and can inform relatives of their location. When a care worker is dispatched by the E-health System to the home, a parking spot is reserved for the care worker via the C3IM system.	A **wearable GPS Positioning device** **Communications Device A** communication device, providing automated dialling to the 24-hour call centre at the user's request (through a remote wearable button) or when triggered by attached actuators. **Long-range microphone and speakerphone** **Panic Button** A wearable "panic button", the call centre to be contacted with a single tap at any time of day In-home health monitoring device. Example - blood pressure monitor, heart rate monitor, ICD or pacemaker monitor In-home motion tracking sensors Alerts could be dispatched to relatives if the monitored person has not moved in a given period of time. In-home smart drug dispenser. A smart drug dispenser is able to report on missed dosages, running out of medication, and other abnormalities.

7.1.5 Use Case 1 Scenario Descriptions and Data Flows

7.1.5.1 Scenario "A": Routing to closest available parking space taking into account both real-time availability of individual parking spaces across different parking providers AND street congestion

In this scenario, driver are routed to nearest available parking structure(s) potentially taking into account particular requirements, such as electric vehicle charging, drivers with special needs (large space around the car, ground floor, etc.).

The following exchanges may occur between DriverNavigationApp and the C3IM platform.

Table 7.1.5.1-1: Scenario "A": Routing to closest available parking space

Query from DriverNavigation app	Response from C3IM system	Sources/sinks of information used to answer the query
What is the closest route to an individual parking spot satisfying my requirements (such as electric vehicle, handicapped, oversized vehicle) taking into account real-time traffic information.	Garage 1 is closer but street to get there is congested, better choose individual parking space rented by Mr X, to which there is a traffic-free route.	Street monitoring system Parking Garage 1 management system Individual parking space rental on behalf of Mr X.
(Having arrived at parking garage). Query: where should I park?	Response: Park at spot 34 on floor 3.	Parking Garage 1 management system.
Reserve place that is available so that it does not get filled before I arrive.	reservation transmitted to parking provider.	state of parking space changed to "booked".

7.1.5.2 Scenario "B": exit from parking structure taking local traffic into account

In this scenario, drivers leaving a parking structure(s) are guided to the recommended exit gate based upon traffic conditions on local streets.

It is assumed that the SmartCity has a SmartParkingBuilding that is near some busy roads and there are often traffic jams caused by cars entering or leaving the SmartParkingBuilding into the stream of traffic. RoadSensors in the streets are used in the TrafficManagementSystem to show that traffic flow is inhibited. In the scenario, SmartParkingBuilding internal signage directs customers to use the exit which is least congested.

The **ParkingManagementSystem** subscribes for access to data from the **TrafficManagementSystem**, which is generated at intervals by the "**StreetMonitoringSystem**" of the degree of traffic-jam in the street with Gate A. If the published data shows congestion at Gate A higher than a given threshold, then the SmartParkingBuilding ("Parking structure 1 management") direct drivers to Gate B with digital signs.

The following exchanges may occur between DriverNavigationApplication and the C3IM Platform.

Table 7.1.5.2-1

Query from DriverNavigation app	Response from C3IM platform	Sources of information used to answer the query
What is the recommended exit taking into account street congestion	Response: Exit from gate 1b onto street 2	Street monitoring system Parking Garage 1 management system

The following exchanges may occur between ParkingManagerApplication and TrafficManagementSystem.

Table 7.1.5.2-2

Query/Notification from DriverNavigation app	Response from C3IM platform	Sources of information used to answer the query
What is the recommended exit	Response: Exit from gate 1b onto street 2	Street monitoring system Parking Garage 1 management system

Table 7.1.5.2-3: Scenario "B": exit from parking structure taking local traffic into account

Query/Notification from Parking Management System	Response from C3IM platform	Sources of information used to answer the query
Notification: traffic conditions on Street 1 and Street 2	Response: Noted	n/a
Query: traffic conditions on Street 1 and Street 2	Response: Street 1 is impeded, Street 2 is unimpeded	Traffic Management System Street monitoring system

7.1.5.3 Scenario "C": Entry to Private Parking Space Rented on Temporary Basis

In this scenario, an owner of a private parking space makes it available for rent using an application which is connected to a C3IM platform. This makes it possible for drivers searching for available spots to be made aware of the facility and terms under which it is available.

The C3IM platform also allows interconnection with the **TrafficManagementSystem** of the city. When the parking space has been allocated, the **DriverNavigationSystem** navigates the driver to the correct location. In the case where the street access would be controlled by a bollard, the **TrafficManagementSystem** actuates the bollard to lower it and allow the car to pass. The **PrivateParkingSpaceManager** opens the gate, garage door, or other barrier to allow the car to enter.

Table 7.1.5.3-1

Query from DriverNavigation app	Response from C3IM platform	Sources of information used to answer the query
Reserve a private parking space near me	Response: Private parking space at location XYZ is reserved	PrivateParkingSpaceManager
Arrived at parking, open the bollard	Response: Bollard is opened	TrafficManagementSystem
Arrived at gate, open the gate	Response: Gate is opened	PrivateParkingSpaceManager

7.1.5.4 Scenario "D": Smart Parking Facility Manager Queries

The owner of the Parking House can judge demand/supply by using the **parking manager application** of the **ParkingManagementSystem** to provide answers to questions about demand in the neighbourhood. The neighbourhood is assumed to be delimited in some way (a named area, geographic coordinates, etc.).

Table 7.1.5.4-1: Scenario "C": Entry to Private Parking Space Rented on Temporary Basis

Query/Notification from Parking Management System	Response from C3IM system	Sources of information used to answer the query
Query: How many people are trying to find a parking place in the neighbourhood?	Response: There are 18 drivers looking for parking spaces in the neighbourhood	Traffic Management System Street monitoring system
Query: How many electric vehicles are trying to find a charging place in the neighbourhood?	Response: There are 3 drivers looking for electric vehicle charging spaces in the neighbourhood	Traffic Management System Street monitoring system
Query: How many drivers with disabilities are trying to find a suitable parking place?	Response: There is 1 driver looking with disabilities trying to find a suitable parking space in the neighbourhood.	Traffic Management System Street monitoring system
Query: How many parents with children are trying to find a suitable (specially allocated: wide, near exit) parking space?	Response: There are 0 parents with children trying to find a suitable (specially allocated: wide, near exit) parking space?	Traffic Management System Street monitoring system

7.1.5.5 Scenario "E": Reserved Parking for Care workers responding to in-home monitor alarm

Municipalities such as Pilea-Hortiatis in Greece operate an eHealth at home pilot supporting around 50 registered homes in the municipality area. When an in-home monitoring device triggers an alarm, health care personnel are notified (by mobile phone), a parking space is assigned (booking, occupied, sign), the licence plate of the approaching car is white-listed (ALPR) and an estimated time of arrival is provided.

Table 7.1.5-5-1: Scenario "E": Reserved Parking for Care workers

Query from Ehealth System	Response from C3IM system	Sources of information used to answer the query
Query: Priority Parking Available for license plate XYZ123? avoiding congested streets ** add license and time of arrival - see previous writeup	Response: Priority Parking place A1 in Parking A Reserved for 15 minutes for XYZ123	Street monitoring systems Parking Garage 1 management system

7.1.6 Use Case 1 Entities instances graph

Figure 7.1.6-1 uses the general information model of ISG C3IM (entities, properties, relationships, values) to show the instances used in the example. This information model is not intended to represent a complete real environment because it is only intended to illustrate the entities used in the scenarios above.

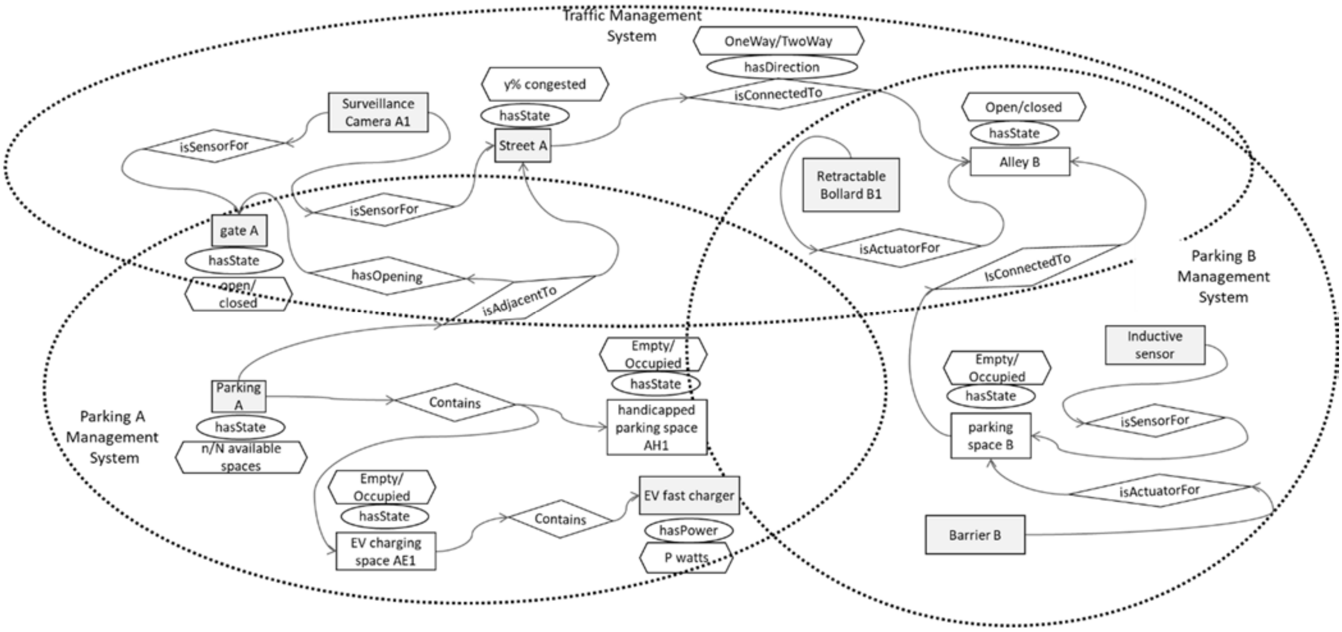

Figure 7.1.6-1: Instance graph example showing 2 distinct Parking Systems and Traffic Management System

The terms used in this diagram to describe entities and properties are not final or even recommended for use in C3IM systems, and just meant for easy understanding in the context of the present document.

According to EC recommendation, data exchange in this domain should comply with DATEX II: https://data.europa.eu/euodp/en/data/dataset/etpa.

In DATEX II, a property such as "parkingNumberOfSpaces" is defined, to be used to describe the maximum number of parking spaces in a parking structure Yet, though this recommendation is very comprehensive, it does not include properties such as those used above for the *instantaneously* available number of spaces (rather than the *permanent* maximum number), or properties such as spaces reserved for electric vehicles!

7.2 Use Case 2: Smart Street Lighting

7.2.1 Use Case 2 Introduction and Assumptions

Street lighting consumes a large amount of energy and large proportion of a city's energy budget. If street lighting is used only when required, such as when traffic is flowing, during adverse weather or low light, then much energy could be saved. Traffic can comprise motor vehicles, cyclists, and pedestrians. Various studies and commercial trials have demonstrated a range of savings, which depends on many individual factors (including safety issues) [i.8].

For this use case, means to detect presence or absence of traffic is required.

A potential drawback of this service is that lights cycling on-and-off may disturb residents, so the use case should provide tools to control cycling (e.g. to make it not too frequent, to use gradual transitions, etc.).

7.2.2 Use Case 2 Information Flow Diagram

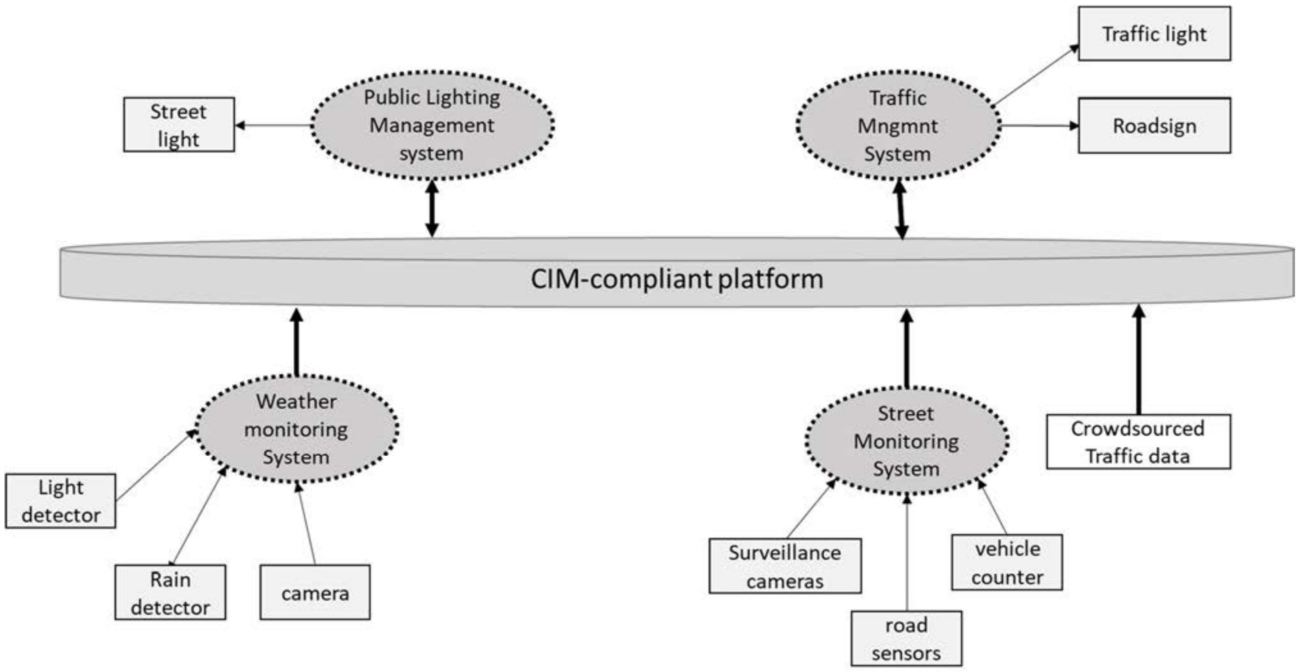

Figure 7.2.2-1: Context Information Exchange between Agents and Data Sources/Actuators in Smart Street Lighting Use Case

7.2.3 Use Case 2 Stakeholders

The Smart Street Lighting Stakeholders, Agents and Entities are shown below.

Table 7.2.3-1: Use Case 2 Stakeholders

Stakeholder	Role in Use Case
Local Smart City planning authorities	The government of a Smart City seeks to manage lighting to reduce ambient light pollution and to reduce energy consumption. It deploys infrastructure such as **TrafficManagementSystem** and **StreetMonitoringSystem** to support drivers and parking facility mangers.
Street Users	Drivers of motor vehicles, cyclists, and pedestrians.
Traffic Management Contractor	A contractor who works with the Smart City to deploy **TrafficManagementSystem.**
Lighting Management Contractor	A contractor who works with the Smart City to deploy **LightingManagementSystem.**

7.2.4 Use Case 2 Agents and Data Source/Sink Entities

Table 7.2.4-1: Use Case 2 Agents and Data Source/Sink Entities

Agent	Agent Description/Data Handling	Data Source/Sink Entity
TrafficManagementSystem	A system operated by the Smart City to help manage traffic flow. It integrates information from sources as such as **StreetMonitoringSystem** and provides information to the **LightingManagementSystem**, using an appropriate API about traffic light conditions.	
LightingManagementSystem	A system used by the Smart City and Traffic Management Contractor to manage and control IoT enabled street lighting assets. It makes use of an appropriate API to interact with the **TrafficManagementSystem**.	Light detector User smartphone
WeatherMonitoringSystem	A system used to measure weather conditions by monitoring sensors placed in various locations within a city	
StreetMonitoringSystem	A system providing information about current street occupancy levels.	**Sensor** installed in the roadway to indicate road occupancy. **Traffic flow monitor**/**congestion detector**

7.2.5 Use Case 2 Scenario Descriptions and Data Flows

7.2.5.1 Scenario "A": Lighting Levels Depending on Traffic Presence

In this scenario, lighting levels are changed according to detected traffic levels in the immediate vicinity.

The following exchanges may occur between LightingManagementSystem and StreetMonitoringSystem.

Table 7.2.5.1-1: Scenario "A": Lighting Levels Depending on Traffic Presence

Query/Notification from LightingManagementSystem	Response from C3IM system	Sources of information used to answer the query
Subscribe to notifications for traffic in vicinity X	Vehicle Traffic present in vicinity X	StreetManagementSystem
	Vehicle Traffic no longer present in vicinity X	StreetManagementSystem
Notification that vehicle traffic is present in vicinity X		
Notification that pedestrian traffic is present in vicinity X		n/a
Notification that bicycle traffic is present in vicinity X		n/a

7.2.5.2 Scenario "B": Lighting Levels Depending on Weather Conditions

Inclement weather leads to reduced visibility which creates safety issues for pedestrians and drivers. Weather is not uniform across the city and lighting levels should be adjusted on specific conditions in the vicinity.

The Lighting Management System subscribes to the Weather Observation System on a per area basis. When weather conditions are observed this results in reduction of light (poor visibility) or increased light (high visibility), changes in lighting levels are triggered.

Table 7.2.5.2-1: Scenario "B": Lighting Levels Depending on Weather Conditions

Query/Notification from LightingManagementSystem	Response from C3IM system	Sources of information used to answer the query
Subscribe to notifications for weather in vicinity X	Ambient Light Level in Vicinity X below threshold	Weather Monitoring System
	Rain in vicinity X	Weather Monitoring System
	Snow in vicinity X	Weather Monitoring System
	Fog in vicinity X	Weather Monitoring System

7.2.5.3 Scenario "C": Lighting Levels Depending on Traffic Management Decisions

In this scenario, lighting levels are changed according to traffic light state. For example, a traffic light controlling traffic which will pass near a streetlight might trigger a decision to increase lighting levels.

The following exchanges may occur between LightingManagementSystem and the C3IM System.

Table 7.2.5.3-1: Scenario "C": Lighting Levels Depending on Traffic Management Decisions

Query/Notification from LightingManagementSystem	Response from C3IM system	Sources of information used to answer the query
Subscribe to notifications for traffic light in vicinity X	Traffic Light XYZ changed to green	TrafficManagementSystem
	TrafficManagementSystem	TrafficManagementSystem

7.2.5.4 Scenario "D": Lighting Levels Depending on Crowdsourced Data

In this scenario, lighting levels are changed according to data made available by smart phone users. A smart phone user may indicate his/her presence either using location tracking or via an application. The smart lighting system may adjust lights to accommodate the expected or actual presence of a user in a given location. The system could provide special lighting levels depending on need of pedestrian, for example a handicapped or elderly person may need higher lighting levels.

The following exchanges may occur between LightingManagementSystem and the C3IM System.

Table 7.2.5.4-1: Scenario "D": Lighting Levels Depending on Crowdsourced Data

Query/Notification from LightingManagementSystem	Response from C3IM system	Sources of information used to answer the query
Subscribe to notifications for crowd source data about pedestrian in Vicinity X	Priority pedestrian (for example elderly) is in Vicinity X	Crowd source data
	No pedestrian in in Vicinity X	Crowd source data

7.2.6 Use Case 2 entity instances graph

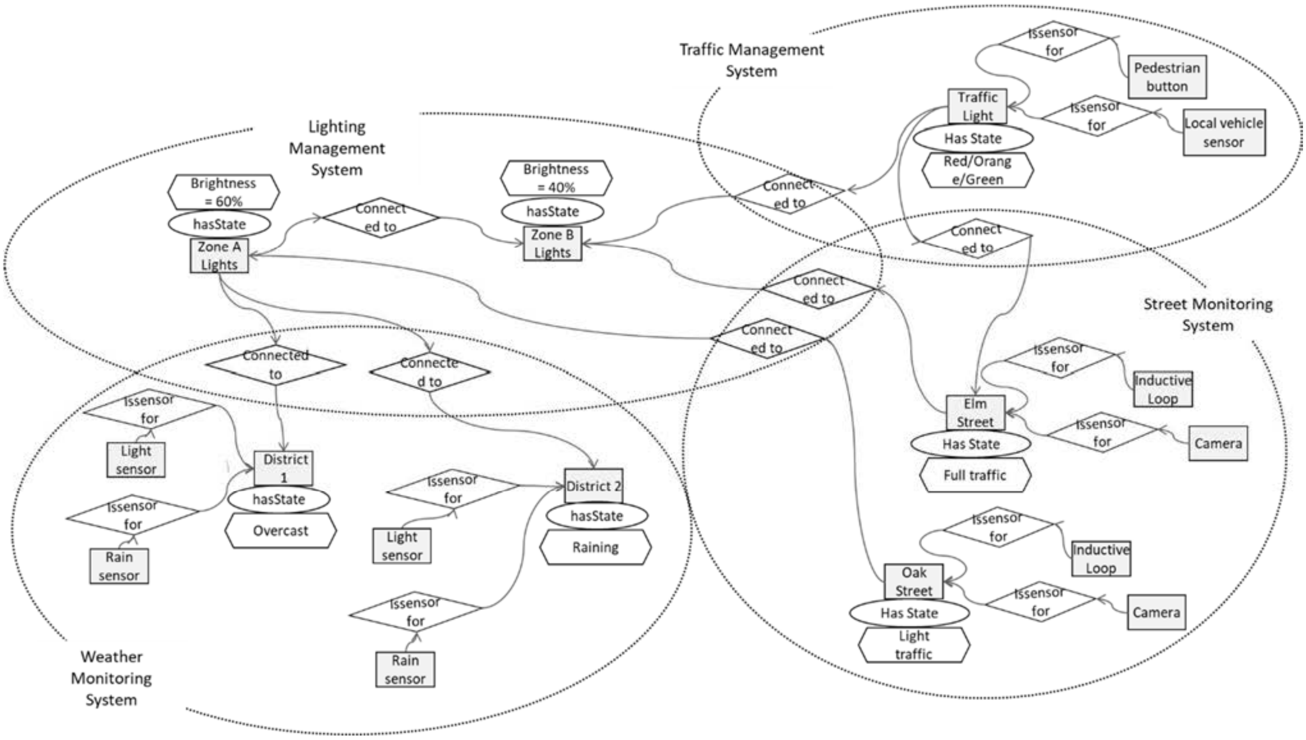

Figure 7.2.6-1: Use Case 2 Instance Graph example

7.3 Use Case 3: Traffic Management & Pricing based on Air Quality, Congestion and other KPIs

7.3.1 Use Case 3 Introduction

Planning authorities seek to optimize traffic flow taking into account current traffic and other conditions and charge for driver access to core areas accordingly. Optimization criteria can include for instance, current congestion, reducing accident probability, improving air quality and mitigating noise. This traffic management use case illustrates the value of "cross cutting" context information.

In London, the congestion charging mechanism is well established, but the congestion charging area is fixed, and the charge does not vary with the actual volume of traffic. With the advent of the IoT it would be possible to implement road pricing schemes where the charge to use a particular route could vary based on the actual congestion on the route (rather than the theoretical congestion), reducing current air pollution build-ups and other factors.

Cities such as Paris or Berlin experience problems with air pollution from vehicles (especially NOx, SO2 and PM10 and PM25 particulates). Novel ways are being considered by authorities to reduce pollution levels of these in order to meet EU directives.

NOTE: See https://www.londonair.org.uk/LondonAir/Default.aspx.

This use case illustrates potential services that may improve air quality through the use of IoT-enabled air quality sensors, information about polluting properties of particular vehicles and intelligent routing decisions. If it was possible to estimate the relative air quality of different routes then it would be possible to route traffic over less polluted routes, thus potentially reducing peak pollution levels and providing an attractive route to road users, especially pedestrians and cyclists. This could be implemented using an air-quality routing option on a navigation application.

Drivers could also be incentivized to use less polluted routes by implementing air quality-based charging. With a dense network of air quality sensors, it would also be possible to vary the price charged depending on the current air quality of a particular route (air quality-based charging).

7.3.2 Use Case 3 Information Flow Diagram

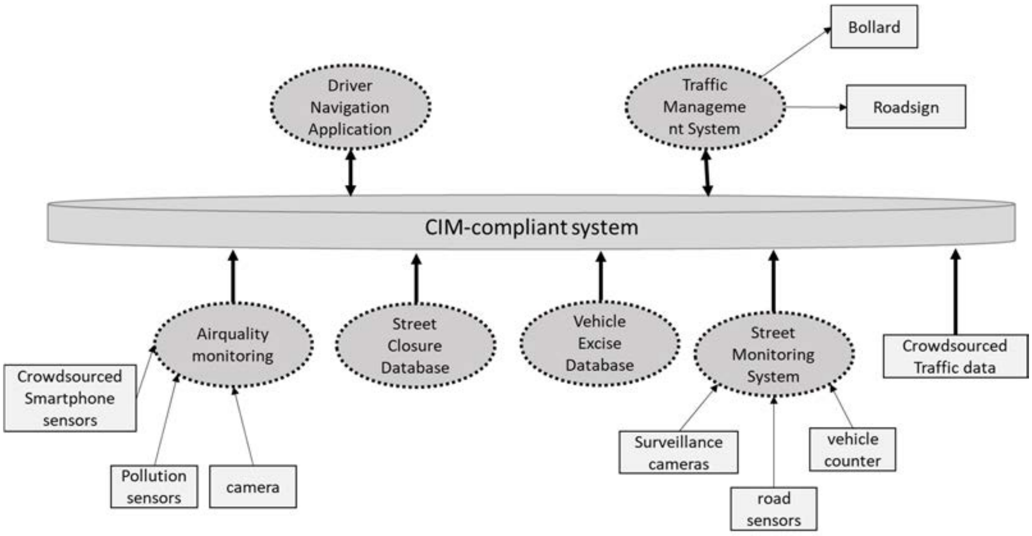

Figure 7.3.2-1: Context Information Exchange between Agents and Data Sources/Actuators for Traffic Pricing Based on Selected KPIs

7.3.3 Use Case 3 Stakeholders

Table 7.3.3-1: Use Case 3 Stakeholders

Stakeholder	Role in Use Case
Local Smart City planning authorities	The government of a Smart City seeks to improve air quality through intelligent routing of traffic. The Smart City may include air pollution charging into pricing for vehicles driving in the city centre. Or, the Smart City may provide information to drivers so that they may voluntarily adopt pollution-reducing driving decisions.
Driver	Socially conscious driver may include air pollution-impacting driving parameters in vehicle routing decisions. Drivers may be charged for bringing vehicles into polluted zones.
SmartphoneUser	People who download an app to allow their Smartphone to send air quality readings to a database such as www.londonair.org.uk, perhaps with some kind of payment.
Traffic Management Contractor	A contractor who works with the Smart City to deploy TrafficManagementSystem. In this use case, it computes available access for drivers and access price depending on estimated air quality impact, and provides options to the driver via the Driver Navigation System.
Air Quality Monitoring Authority	An authority or business who provide air quality monitoring services, aggregates data from multiple sensors, user smart phones, etc. and provides the air quality information to service providers.
Vehicle Excise Database Authority	The provider of vehicle information such as pollution characteristics

7.3.4 Use Case 3 Agents and Data Source/Sink Entities

This use case requires a network of air quality sensors. Sensors from different locations provide air quality context information which can be made available by a C3IM server. In the case that air quality sensors are provided by personal smartphones, local (to the smartphone) measurements can be taken into account so as to select routes based on local pollution levels.

Table 7.3.4-1: Use Case 3 Agents and Data Source/Sink Entities

Agent	Agent Description/Data Handling	Data Source/Sink Entity
TrafficManagementSystem	A system operated by the Smart City to help manage traffic flow. It integrates information from sources as such as **StreetMonitoringSystem** and AirQualityMonitoringSystem using an appropriate API.	
LightingManagementSystem	A system used by the Smart City and Traffic Management Contractor to manage and control IoT enabled street lighting assets. It makes use of an appropriate API to interact with the **TrafficManagementSystem**.	Light detector User smartphone
AirQualityMonitoringSystem	A system operated by the Smart City to help manage Air Quality. It integrates information from sources as smart phones and **VehicleExciseDutyDatabaseVehicleExciceDutyDatabase** and provides information to the **DriverNavigationApplication**, using an appropriate API.	
StreetMonitoringSystem		**Sensor** installed in the roadway to indicate road occupancy. **Traffic flow monitor/congestion detector** **Camera** with vehicle/pedestrian detection and tracking software
Street closure database	This is a database providing information about street closures and roadworks.	**contractors provide the information to city officials**
DriverNavigationSystem	A system used by to determine route for drivers. It accesses information from **TrafficManagementSystem via an appropriate API** and interacts with the driver's navigation device.	DriverNavigationDevice (satnav)
VehicleExciseDutyDatabase	A system used to store information about vehicles registered by an authority.	

7.3.5 Use Case 3 Scenarios

7.3.5.1 Scenario "A": Traffic Management to reduce Pollution Peak Levels

In this scenario, the following services are described:

- Drivers are routed to avoid highly polluted areas in an effort to reduce peak pollution levels.

The following exchanges may occur between DriverNavigationApplication and the C3IM System.

Table 7.3.5.1-1: Scenario "A": Traffic Management to reduce Pollution Peak Levels

Query/Notification from DriverNavigationApplication	Response from C3IM system	Sources of information used to answer the query
Query: What are pollution hotspots in Zone (delimited geographic zone)	Response: Pollution hotspots are as follows: (list of pollution hotspots by location)	AirQualityManagementSystem

7.3.5.2 Scenario "B": Traffic Management to reduce Pollution Peak Levels with price incentive

In this scenario, drivers are routed to avoid highly polluted areas in order to minimize cost to drivers for selected route.

The following exchanges may occur between DriverNavigationApplication and AirQualityManagementySystem.

Table 7.3.5.2-1: Scenario "B": Traffic Management to reduce Pollution Peak Levels

Query/Notification from DriverNavigationApplication	Response from C3IM system	Sources of information used to answer the query
Query: What are pollution costs (cost to traverse indicated geographical zone) for Zone 1 and Zone 2 with indicated vehicle parameter/registration number	Response: Pollution hotspots are as follows for this vehicle: (list of pollution hotspots by location)	AirQualityManagementSystem VehicleExciseDatbase

7.3.5.3 Scenario "C": Traffic Routing to Avoid Polluted Routes

In this scenario, cyclists are routed to select less polluted routes.

The following exchanges may occur between DriverNavigationApplication and C3IM System.

Table 7.3.5.3-1: Scenario "C": Traffic Routing to Avoid Polluted Routes

Query/Notification from DriverNavigationApplication	Response from C3IM system	Sources of information used to answer the query
Query: What is pollution level in Zones X	Response: Pollution level is as follows	AirQualityManagementSystem
Query: What is pollution level in Zones Y	Response: Pollution level is as follows	AirQualityManagementSystem
Query: What is pollution level in Zones Z	Response: Pollution level is as follows	AirQualityManagementSystem

7.3.5.4 Scenario "D": Access Price for downtown depends on Congestion and Size of Vehicle

In this scenario, price to enter congested vehicle zones depends on current congestion, characteristic of vehicle.

The following exchanges may occur between DriverNavigationApplication and AirQualityManagementySystem.

Table 7.3.5.4-1: Scenario "D": Access Price for downtown depends on Congestion and Size of Vehicle

Query/Notification from DriverNavigationApplication	Response from C3IM system	Sources of information used to answer the query
Query: What is pricing for indicated vehicle parameter/registration number to traverse Zone A	Response: 3 €	AirQualityManagementSystem VehicleExciseDatbase StreetMonitoringSystem

7.3.5.5 Scenario "E": Information Service on Pollution Levels and Pricing

Table 7.3.5.5-1: Scenario "E": Information Service on Pollution Levels and Pricing

Query/Notification from Smartphone Pollution App	Response from C3IM system	Sources of information used to answer the query
Report pollution readings in previous locations		
What are pollution readings in location X		AirQualityManagement System
What is the average air quality in location X for times Y [day/week/year]?		AirQualityManagement System
What is the average air quality in location X for times Y [day/week/year]?		AirQualityManagement System
What was the air quality in location X for time Z		AirQualityManagement System
What was the air quality in location X for time Z		AirQualityManagement System
What are pollution costs to traverse Zone A with vehicle pollution characteristics as indicated		AirQualityManagement System VehicleExciseDatbase StreetMonitoringSystem

7.3.6 Use Case 3 Entities Instances Graph

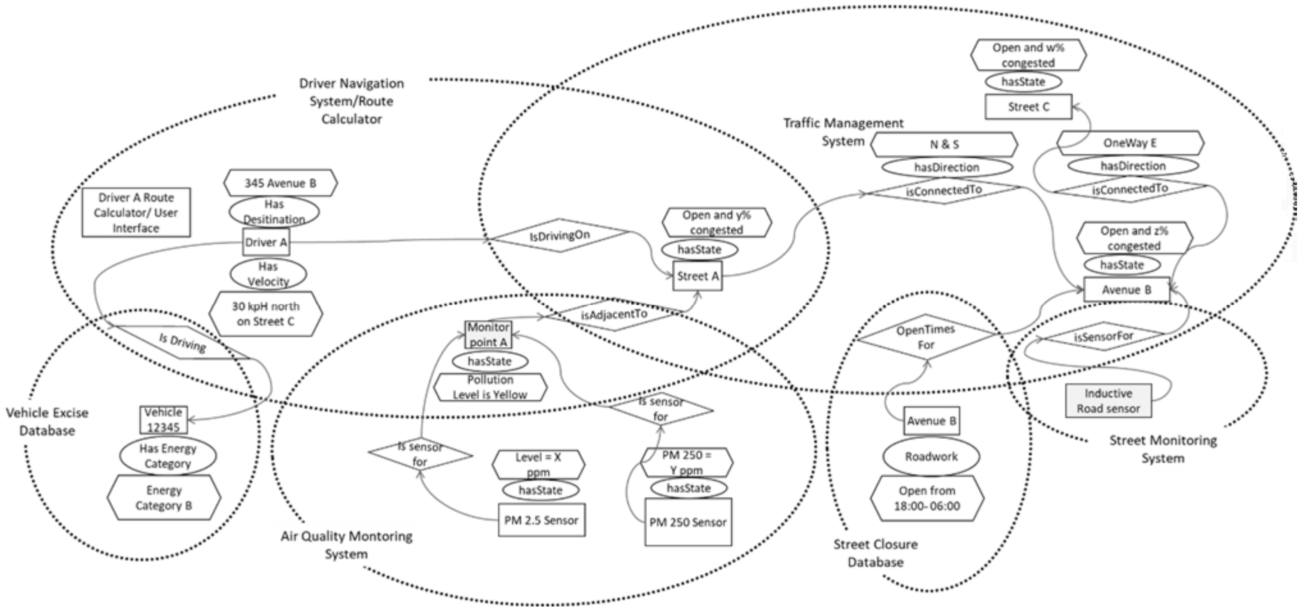

Figure 7.3.6-1: Use Case 3 Entities Instances Graph

7.4 Use Case 4: Crowd Monitoring and Emergency Response

7.4.1 Use Case 4 Introduction and Assumptions

Problem: Crowd/Queue detection is important in modern society to manage public places and vacation resorts for different situations, especially in case of emergency. The results of crowd/queue detection need to be combined with data from other sources to support knowledge discovery, decision making and smart recommendations. Wifi sniffer, Bluetooth sniffer and camera monitoring with image process are several technologies achieving crowd/queen detection. In an overcrowded place, when a crisis or an emergency occurs, the population needs to be evacuated while the injured people need to be transported to hospital.

In order to show a concrete use case in the present document, a vacation resort is taken as an example showing management and emergency response. In the large vacation resort, many facilities exist for entertainment. In order to improve the vacationers' experience, queue detection is applied in front of entertainment facilities, while crowd detection can be applied in internal/external areas to detect crowd level. The data from queue/crowd detection is used by resort management system to provide real time information, make smart recommendations for vacationers, propose special offers and respond to emergency. The local authorities also use the data on a city scale to study the vacationers in the resort and tourists in the city.

Solution: Devices for crowd detection, installed in different areas of the place, provide crowd information and can be accessed by other services, while the place management system provides information on available resources and real time information relating to the location. The police department obtains a range of data, including the status of the emergency situation, traffic and road congestion in the vicinity, and information about the location and numbers of people. This is required to evacuate people from the crisis scene. Medical responders obtain information about available health care resources (hospitals, ambulances, doctors), and about traffic conditions. This is required to organize first aid and to transport the injured to available hospitals. IoT devices (e.g. cameras, sensors) and smartphones allow the collection of location and status data about people, Other systems can provide information on the incident, disposition of emergency response teams, equipment and facilities.

7.4.2 Use Case 4 Information Flow Diagram

Figure 7.4.2-1 the agents interacting with a C3IM-compliant platform and the corresponding C3IM-compliant information flows that support this use case. The data source/sink entities (sensors, actuators) associated with each agent are also shown.

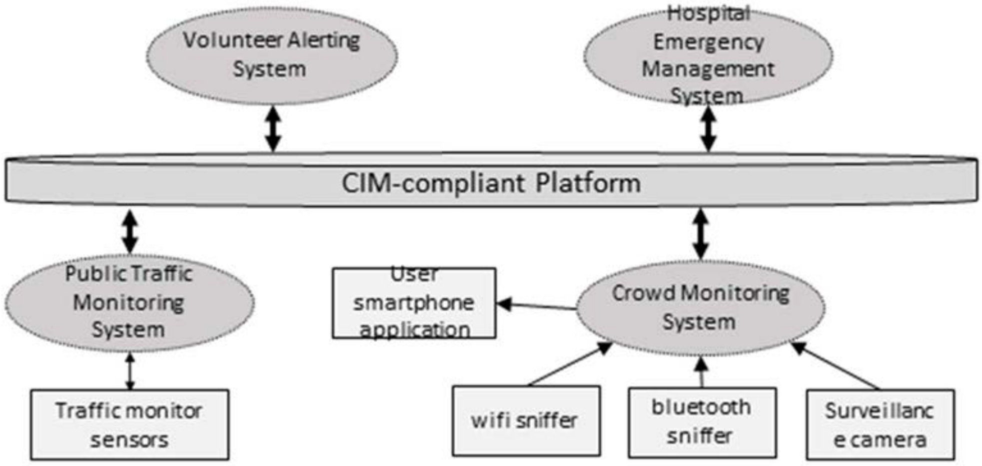

Figure 7.4.2-1

7.4.3 Use Case 4 Stakeholders

Table 7.4.3-1: Use Case 4 Stakeholders

Stakeholder	Role in Use Case
Resort Owner	The stakeholder operates the resort services, and deploys resort management system, crow/queue detection system, and user resort system to provide crowd management and to assist visitors.
Resort Visitors (Vacationers)	In normal scenarios, vacationers receive resort information and special offers by installing user resort app. In emergency cases, receives instructions on same app regarding evacuation routes.
Hospital Manager	Hospital manager is in charge of the interfaces with resort to provide information on available medical resources and to manage allocation of resources.
Volunteer Group	The first-aid groups provide first-aid volunteer services to around areas with a volunteer management system for tasks and resources management.
Police department	The police department regulates the local traffics and provides the public traffic monitoring system.

7.4.4 Use Case 4 Agents and Data Source/Sink Entities

In table 7.4.4-1, a Data Source is an entity such as sensor which provides data to an agent, and a Data Sink is an entity such as an actuator which is controlled by an agent. (The association of Agent and Entity is not meant to be restrictive, in other words an Entity could provide data from more than one Agent.)

Table 7.4.4-1: Use Case 4 Agents and Data Source/Sink Entities

Agent	Agent Description/Data Handling	Data Source/Sink Entity
Crowd/QueueDetectionSystem	A system operated by the Resort to: • Get Crowd/Queue information by portable device sniff. • Send data to Resort Management System.	wifi sniffers bluetooth sniffers cameras
ResortManagementSystem	A system operated by the Resort to: • Get data from Crowd/Queue detection agents and other agents. • Provide data and resource access to Resort. • Provide recommendations.	
HospitalManagementSystem	• Provide data about available medical resources (practitioners, equipments, beds, blood, etc.). • Manage first aid and medical car processes.	
VolunteerManagementSystem	• Provide data about available medical resources (volunteers, equipments). • Manage first aid processes.	
PublicTrafficMonitoringSystem	• Provide information about traffic and congestion.	Traffic Monitor sensors
UserResortSystem	• Normal period: user's application to get real time resort information and commercial recommendations. • Emergency period: provide users with recommended evacuation paths.	

7.4.5 Use Case 4 Scenario Descriptions and Data Flows

7.4.5.1 Scenario "A": Population Evacuation taking into account resort crowd and external traffic info

This scenario aims at providing vacationers with evacuated paths taking into account crowd in resort and external traffic info. It can take place in resort indoor and outdoor areas.

The resort management system, traffic monitoring system, User Report System, and Crowd/Queue management System are involved in this scenario. The following data flows may occur.

Table 7.4.5.1-1

Query/Notification from Resort Management System	Response from C3IM platform	Sources of information used to answer the query
What is the crowd level in one resort area?	This area is empty/occupied/overcrowded	Crowd/Queue management system
Notification: crowd level updates		
What is the traffic status in one street?	The street is empty/jammed/blocked	Public traffic monitoring system
Notification: traffic status updates		

Table 7.4.5.1-2: Scenario "A": Population Evacuation taking into account resort crowd and traffic info

Query/Notification from User Report System	Response from C3IM platform	Sources of information used to answer the query
What is the crowd level in one resort area?	This area is empty/occupied/overcrowded	Crowd/Queue management system
Notification: crowd level updates		
What is the traffic status in one street?	The street is empty/jammed/blocked	Public traffic monitoring system
Notification: traffic status updates		
What is the recommended evacuation path from my position?	Path: IndoorAreaA->OutdoorAreaB->street1	Resort management system
Notification: path updates		

7.4.5.2 Scenario "B": First aid in resort during emergency taking into account resort crowd and available resources

This scenario aims at providing injured vacationers with medical aid taking into account crowds in the resort and available medical resources. It can occur anywhere in the resort.

The resort management system, traffic monitoring system, User Report System, volunteer management system and hospital management system are involved in this scenario. The following data flows may occur.

Table 7.4.5.2-1

Query/Notification from Hospital Management System	Response from C3IM platform	Sources of information used to answer the query
Where is the location of the emergency/injuries?	Location	Resort Management System User Report System
What is the recommended path for medical assist?	Path: Street1->OutdoorAreaB-> IndoorAreaA	Crowd/Queue management system Traffic monitoring system Resort management system
Notification: path updates		
How many people need to be transferred to hospital?	Number of juries to transfer	Resort management system User Report System
Notification: number updates		

Table 7.4.5.2-2: Scenario "B": First aid in resort during emergency taking into account resort crowd and available resources

Query/Notification from Volunteer Management System	Response from C3IM platform	Sources of information used to answer the query
Where is the location of the emergency/injuries?	Location	Resort Management System User Report System
What is the recommended path for medical assist?	Path: Street1->OutdoorAreaB-> IndoorAreaA	Crowd/Queue management system Traffic monitoring system Resort management system
Notification: path updates		
How many people need to be transferred to hospital?	Number of juries to transfer	Resort management system User Report System
Notification: number updates		

7.4.6 Use Case 4 Entity instances graph

Figure 7.4.6-1 uses the general information model of ISG CIM (entities, properties, relationships, values) to show what would be a tiny subset of all entities that would be actually involved, it is neither complete nor and it is only intended to illustrate the use cases below.

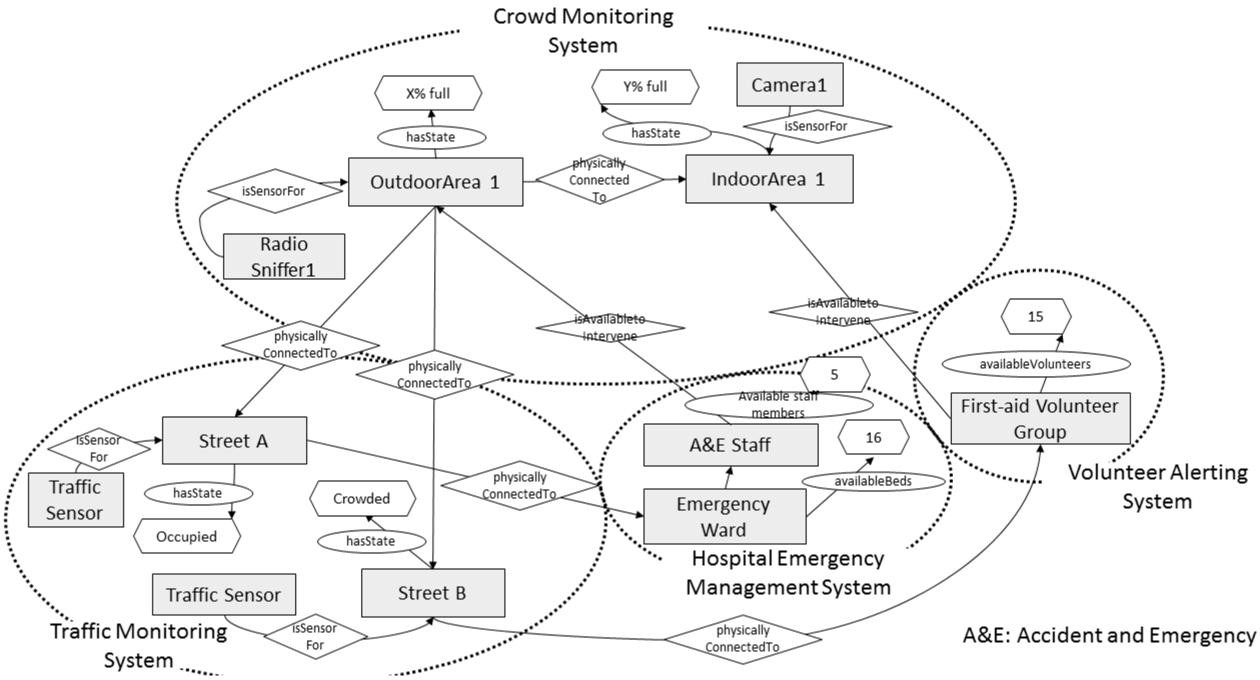

Figure 7.4.6-1: Use Case 4 Entity instances graph

Population evacuation is more efficient when considering both resort internal crowd and external traffic info. Medical support is more efficient when considering resort internal crowd and resort available medical resources; while the transport of injuries is when taking into account available hospital resources.

7.5 Use Case 5: Management of Optical Fibre Network Deployment

7.5.1 Use Case 5 Introduction and Assumptions

Problem: The optical fibre deployment in cities and towns are ongoing worldwide to replace traditional ADSL services and provide faster and more stable connections. This is usually a time-consuming process starting from current deployment status investigation and deployment planning, to realization of technical works and then to commercialize offers to connect public and private users. Along the network deployment, multiple actors from public organizations and private companies are involved for frequent information exchange and decision makes to ensure the success network deployment, which is positioned as trusted third parties for the management of the digital ecosystem. The security of digital access, the storage of performance data and the resilience of the system should be guaranteed. For example, if a deployment operator is missing, the related data is supposed to remain available and usable. Moreover, each agent, according to his role and the associated rights may or may not access, search and share related data. In particular, the data (e.g. measurement of a smart meter, satellite image), as well as people (e.g. technician of a municipality) can be geolocated and that this geolocation can impact access rights.

A concrete use case is presented in the present document for the construction of an optical fibre telecommunication network in the public area of French Southern-Alps region. The public initiative network to be built concerns 100 municipalities, for a total of 75 000 optical fibre plugs. This network will serve both residents and businesses and all public sites, and it will be 100 % optical fibre by 2021.

Solution: The project owner of the optical fibre network decides the region to deploy and queries the current deployment status from city and town minimalities; based on the feedback, the project owner identifies the exact actions to be taken in each sub areas and outsourcing technical companies. Technical companies realize the deployment in fields. In the meantime, the project owner manages and supervises the deployment, the cities and the citizens involved are informed about the progress and influence of the ongoing work. At the end, operators commercialize the optical fibre network and connect individual and public users.

7.5.2 Use Case 5 Information Flow Diagram

Figure 7.5.2-1 the agents interacting with a C3IM-compliant platform and the corresponding C3IM-compliant information flows that support this use case. This is a non-IoT use case driven by data flows, and the (non-IoT) data source/sink entities associated with each agent are also shown.

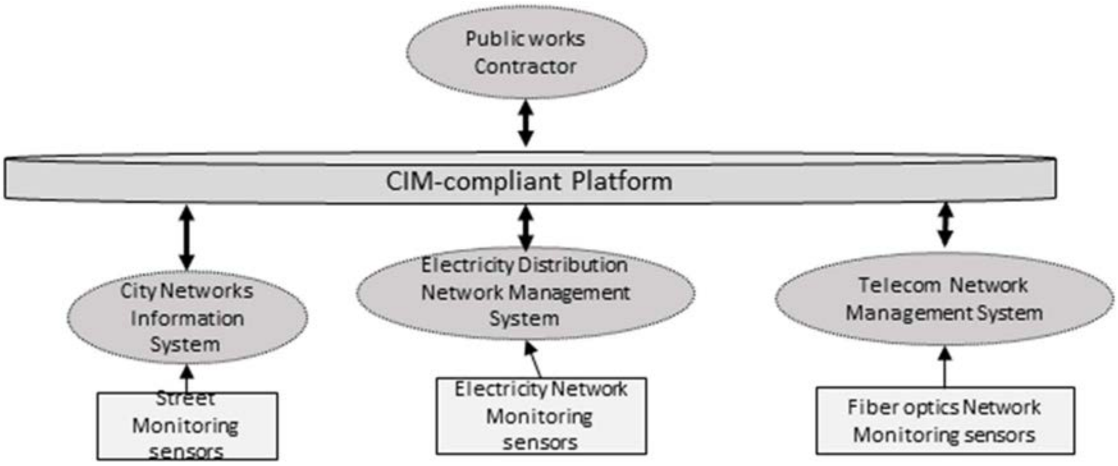

Figure 7.5.2-1: Use Case 5 Information Flow Diagram

7.5.3 Use Case 5 Stakeholders

Table 7.5.3-1: Use Case 5 Stakeholders

Stakeholder	Role in Use Case
Project Owner of Optical Fibre Network	This stakeholder owns the optical fibre network to deploy, recruits contractor to do in-field deployment, and deploys project management system for internal management and external query purpose.
Contractor	The contractor deploys in the cities following the project owner's expectation, and interacts with other network owners (e.g. gas network operator) for information.
City Municipality	City municipality collects all data related to city.
Gas Network Owner	The stakeholder owns the gas network deployed in the same city as the optical fibre network to deploy and operates a gas management system.

7.5.4 Use Case 5 Agents and Data Source/Sink Entities

In table 7.5.4-1, a Data Source is an entity such as sensor which provides data to an agent, and a Data Sink is an entity such as an actuator which is controlled by an agent. (The association of Agent and Entity is not meant to be restrictive, in other words an Entity could provide data from more than one Agent.)

Table 7.5.4-1: Use Case 5 Agents and Data Source/Sink Entities

Agent	Agent Description/Data Handling	Data Source/Sink Entity (Non-IoT)
Project Management System	A system operated by project owner of fibre optical network to: • Get Crowd/Queue information by portable device sniff • Send data to Resort Management System	Optical Fibre Network
City Data System	A system operated by city municipality to: • Get data from Crowd/Queue detection agents and other agents • Provide data and resource access to Resort • Provide recommendations	Building Street District
Contractor System	A system operated by city municipality to: • Provides info about timing, locations, planning • Report deployment progress	Info Panels
Gas Management System	A system operated by gas network owner to: • Provides info about timing, locations, planning • Report deployment progress	Gas Network

7.5.5 Use Case 5 Scenario Descriptions and Data Flows

7.5.5.1 Scenario "A": Network Deployment Planning

In this scenario, the project owner plans to develop a network in certain region and needs to identify the area that the network should be deployed.

The project management system, city data system and gas management system are involved in this scenario. The following data flows may occur.

Table 7.5.5.1-1: Scenario "A": Network Deployment Planning

Query/Notification from Project Management System	Response from C3IM platform	Sources of information used to answer the query
What is the existing deployment of network deployment in the city?	Existing networks (e.g. gas network, electricity network)	City Data System Gas Management System
What are the ongoing constructions in the city?	Construction information with location and timing.	City Data System
Notification: ongoing construction updates		

7.5.5.2 Scenario "B": Network In-Field Deployment

In this scenario, the contractor deploys the network in different areas within the city and informs project manager and city municipality about the planning and progress.

Table 7.5.5.2-1

Query/Notification from Contractor System	Response from C3IM platform	Sources of information used to answer the query
What are the existing deployments in street/building/districts?	Infos about pipelines, building ducts and sub networks	City Data System Gas Management System
What are the ongoing constructions in the city?	Construction A, street B, date	City Data System
Notification: ongoing construction updates		
What is the detailed network to deploy?	Description on optical fibre network	Project Management System

Table 7.5.5.2-2

Query/Notification from Project Management System	Response from C3IM platform	Sources of information used to answer the query
What is the deployment progress?	Area A completed, Area B 65 %	Contractor System
Notification: progress update		

Table 7.5.5.2-3: Scenario "B": Network In-Field Deployment

Query/Notification from Project Management System	Response from C3IM platform	Sources of information used to answer the query
What is the deployment planning?	Planned deployment time in location	Contractor System
What is the exact deployment time each day?	Area A: 9h00-18h00	Contractor System
What is the deployment progress?	Area A completed, Area B 65 %	Contractor System
Notification: progress update		

7.5.6 Use Case 5 Entities instances graph

Figure 7.5.6-1 uses the general information model of ISG CIM (entities, properties, relationships, values) to show the information model of the example. This information model is not complete for real applications because it is only intended to illustrate the use cases below.

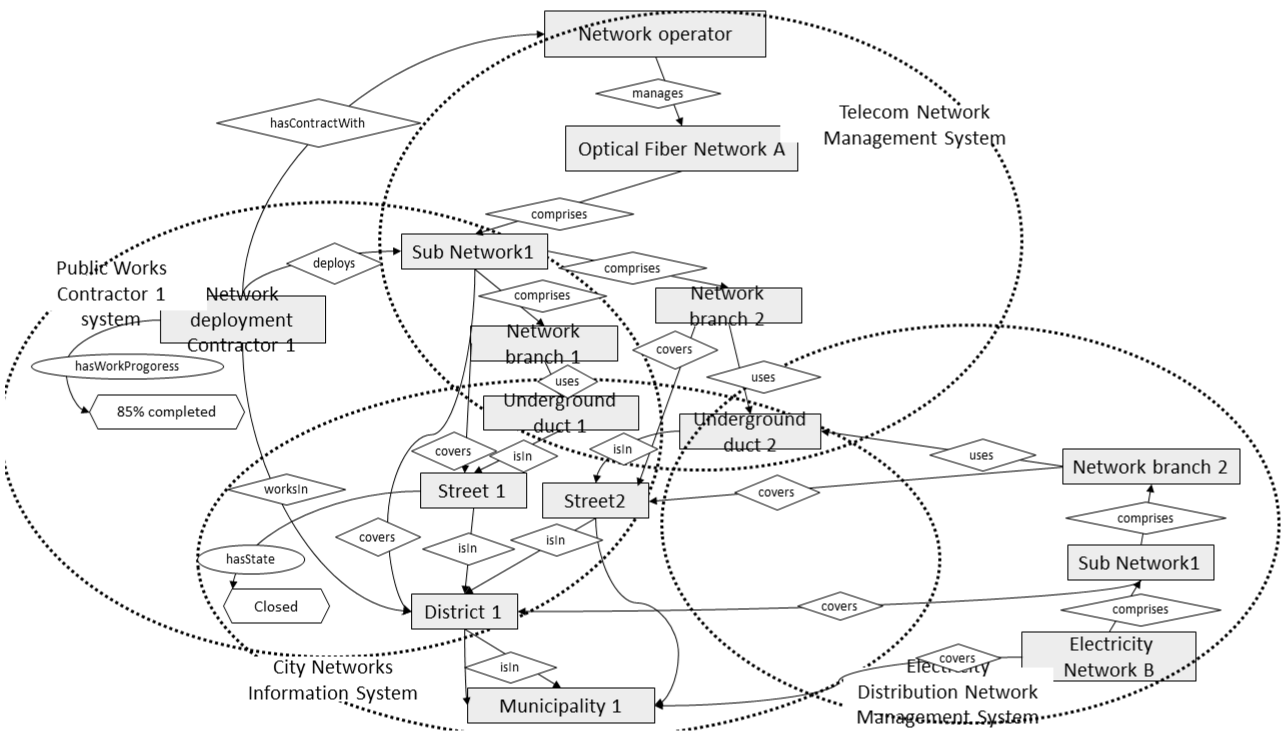

Figure 7.5.6-1: Use Case 5 Entities instances graph

During planning, the project owner is able to check the existing deployment status from city data to reuse existing network (e.g. gas network) to save resource and avoid repeated work. The city municipalities and citizens can be informed by contracts or project owners about the progress of deployment and potential influence, so urban life decisions can be improved by taking these elements into account.

8 Smart Agrifood Use Cases

This clause is reserved for later revisions of the present document.

9 Smart Industry Use Cases

This clause is reserved for later revisions of the present document.

Annex A: Selected "Vertical" Use Cases from the Literature

Before studying some exemplary cross-cutting use cases in detail, it is useful to study in the table below some examples of "vertical" use cases where data is collected and re-used in (proprietary) software to create a service, using examples including (some) open data resources. A number of useful features (capabilities) for a C3IM system can be identified: see column three of table A.1.

Combining parts of two "vertical" use cases can often result in a "cross-cutting" use case, which is similar to the web 2.0 concept of "mash ups". The crucial difference between a mash-up and a C3IM system, which is the aim of the ISG C3IM work, is that a C3IM system should have generality. A mash up usually has just a specifically designed "translation" software or filter between the data of one source and the data from another, where human expertise ensures that corrected data elements are selected and combined. In a C3IM system, the compatibility of the data elements should be discoverable based on the semantics and context information referenced.

Table A.1

Example	Service	Interesting Capabilities (a) - (f)
www.kigafinder.at (Austria)	helps to find kindergartens in Vienna	**a) geospatial tagging**
Mapa do cidadao (Portugal)	is a mobile application providing an overview and map of all public services, with phone numbers and other info	**a) geospatial tagging:** shows citizens all the locations to interact with city government services
Lebensraumur	allows citizens to show location-based ideas for improving the town "green" areas and bike paths	**b) add dynamic user data:** associate objects with geographical locations AND allow citizens to add ad-hoc their own record attributes (e.g. ideas tag, photos)
Campus Wirtschaftsuniversität Wien	shows parking locations and toilets for handicapped people	**c) filter geo-spatial data with other information**: query for objects within a geographic boundary AND with specific attribute
TrafficAccidents	shows locations of all kinds of accidents in 2015, filterable by type (e.g. involving bicycle) also with Time-of-Day animation, to help in traffic planning and accident prevention	**d) show summary statistics of attributes at specific locations**: associate events (i.e. timestamped data records like e.g. traffic accident at a street address) with a geographical location AND query records to show locations of accidents occurring at a certain hour of day/night.
Umweltministerium (Austria)	shows by location many data including e.g. Ozone in semi-realtime and alternatively as a timeline per clicked-on location	**e) show timeline of an attribute:** access past records for an attribute of a specific object by accessing historical data (not only most recent value)
Facts4Stops	correlates streets and houses together with census data to show probable traffic loadings	**f) emulation based on geo-spatial data and other information**: create new query for objects (houses) within a geographic boundary AND query object attributes to get numbers of residents (of certain age range) AND calculate new data for resulting peak-hour road usage of residents
www.geolytix.co.uk (England)	Is a commercial service to help businesses assess optimal retail locations based on geo-mapped data from consensus, school results, entrances to schools, accommodation types, etc.	**g) create " heatmap" of a KPI:** joins many kinds of socially-relevant data and maps a calculated result parameter
360Waste (Portugal)	360Waste collects volumetric information of fill-level of waste containers which allows for more efficient waste collection in Portugal.	**h) sensor values drive dispatching:** waste sensors are geo-located then dynamic waste levels input to improve pick-up planning
TenderGalaxy	is a web application that allows visitors to interactively browse the connections between Dutch government entities, their published tenders and the businesses interested in these tenders.	**i) relationship graphs:** maps business relationships of the city, like friends-of-friends graphs (but latest data is 2016)

Example	Service	Interesting Capabilities (a) - (f)
Bike Citizens (Austria)	links to a cloud database and provides users with the best route by bike to destinations in 300 cities over Europe. Travelled routes can be uploaded and anonymously aggregated to document usage for city planning.	**j) sensor-values-drive-dispatching AND heatmap of KPI**

In summary, some useful characteristics for a C3IM system, based on the examples from "vertical" systems, generalized for all kinds of data, would be:

a) geospatial tagging;

b) geospatial with dynamic user data;

c) filter geo-spatial data with tags;

d) show summary statistics of attributes at specific locations;

e) show timeline of an attribute;

f) emulation based on geo-spatial data and other information;

g) create " heatmap" of a calculated KPI;

h) geospatial sensor values determine routing;

i) relationship graphs;

j) sensor-values-drive-dispatching AND heatmap of KPI.

Annex B:
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The following people have contributed to the present document:

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