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Context Information Management (CIM); Usage of geo-information

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Foreword

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

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document contains the key learning gained from 13 interviews with a variety of key city stakeholders.

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] ETSI GS CIM 050: "Context Information Management (CIM); Aligning with geo-information".

[i.2] The Smart City Strategy of the City of Brussel.

[i.3] Local Digital Twins: Forging the Cities of Tomorrow.

[i.4] A proof of concept to show the ingestion of data into a FROST-Server using the Orion Context Broker API.

[i.5] Recommendation ITU-T Y.4505: "Minimal Interoperability Mechanisms for smart and sustainable cities and communities".

[i.6] Open Geospatial Consortium (OGC): "Web Feature Service".

[i.7] Open Geospatial Consortium (OGC): "OGC APIs - Features".

[i.8] GeoJSON.

[i.9] Open Geospatial Consortium (OGC): "Geography Markup Language (GML)".

[i.10] OGC GeoPackage.

[i.11] Open Geospatial Consortium (OGC): "CityGML".

[i.12] ISO 16739-1:2024: "Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries - Part 1: Data schema".

[i.13] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void

3.2 Symbols

Void

3.3 Abbreviations

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

AI	Artificial Intelligence
API	Application Programming Interface
BIM	Building Information Modeling
CAD	Computer Aided Design
DG	Directorate General
DS4SSCC	Data Space for Smart Communities
GIS	Geographic Information System
GML	Geography Markup Language
GS	Group Specification
IEC	International Electrotechnical Commission
IFC	Industry Foundation Classes
IoT	Internet of Things
IT	Information Technology
JRC	Joint Research Center
JTC	Joint Technical Committee
LD	Linked Data
LDT	Local Digital Twin
MIM	Minimal Interoperability Mechanism
MIM	Minimal Interoperable Mechanism
NGSI	Next Generation Service Interface
NGSI-LD	Next Generation Service Interface Linked Data
OGC	Open Geospatial Consortium
SAREF	Smart Applications REFerence ontology
STA	SensorThings API
SyC	Systems Committee
WFS	Web Feature Service

4 Problem Statement

The present document has been written to provide an accurate picture of how smart cities and territories are using geo-information at the moment, what standards they are using for what purposes and what experiences there are in using NGSI-LD as part of those use cases. The present document also covers the use of geo-information related to environmental issues more generally, as covered by the INSPIRE directive [i.13].

The aim is to be to highlight the key challenges of using NGSI-LD to link to data managed using such standards such as OGC WFS [i.6] and OGC API [i.7] as well as the INSPIRE directive's [i.13] requirements, or encoded using such standards as GeoJSON [i.8], GML [i.9], GeoPackage [i.10], CityGML [i.11] and IFC [i.12]. These challenges would then be addressed by ETSI GS CIM 050 [i.1]. The aim, along with the associated deliverable ETSI GS CIM 050 [i.1], is to enable ETSI to further develop the work on NGSI-LD to:

- specify how to make geodata accessible as Linked Data, how to share spatial (and spatio-temporal) data, and how to make them interoperable with, within, and between systems and territories;
- specify how to both establish and maintain the number of connections between NGSI-LD entities and their geographical 2D/3D representations.

The three families of standards considered; NGSI-LD, Geospatial standards developed by the Open Geospatial Consortium, and BIM and IFC standards developed by BuildingSmart International (see https://www.buildingsmart.org), are all used by cities although often by different departments within those cities.

All three sets of standards need to handle the same set of issues:

- Data about locations and movements.
- Data about urban infrastructure - buildings, roads, bridges.
- How to link different data sources together to provide insight.

However, because of their different focus, they each have their own strengths and weaknesses. At a very high-level:

- NGSI-LD is particularly good at enabling IoT data to be linked with valuable context data to show its significance. It can handle geospatial and building data but only to a certain level.
- OGC standards allow geo-spatial data to be handled to a high degree of sophistication, but can only provide a certain degree of context and building related information.
- BIM/IFC standards provide a rich and detailed way of describing buildings and urban infrastructure, but struggle to indicate precise geographic location and wider context.

The interviews highlighted that smart cities and communities are increasingly recognizing that to tackle almost any urban issues, they need to be able access detailed sets of specific information about location, urban infrastructure and context taken from data collected using these different sets of standards.

They do not need all possible information - just the minimal but "good enough" sets of information relevant to guide them in tackling specific challenges. They are therefore trying to identify practical solutions and "work arounds" that will enable them to gather the information they need from data collected using the different standards. The present document identifies a number of these "work arounds" that cities are using. ETSI, along with OGC and BuildingSmart International, need to see how the standards they develop can be enhanced to support the use of these solutions.

There are many ways to improve ease of integration between different data structured according to different data standards. For instance, it is helpful if the different data sets use common data models for all the key entities, or at least ones that can easily be aligned. Similarly, the use of common identifiers will greatly add data integration. The use of these solutions can greatly enhance the ease of integration between the different types of data.

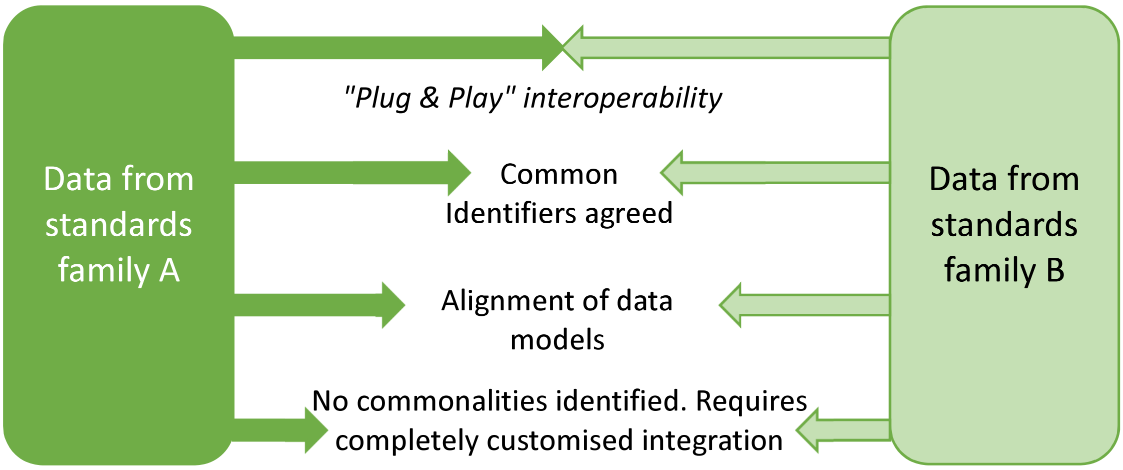

Figure 1: Examples of solutions to improve data integration

It is interesting that OGC have also recognized the need to find alignment with smart data models and linked data and the present document learns from their proof of concept. So, there is an opportunity to work at this from both sides.

The interviews indicated that the key issue is not one or two specific use cases where smart cities and communities are using geospatial standards, but rather that they are increasingly realizing that to tackle almost every challenge they face, they need to be able to bring together information from geospatial data and services and context data from NGSI v2 along with NGSI-LD and other formats using linked data.

5 Methodology

5.1 Information required

The work was aimed at using interviews to identify common use cases where smart cities and territories need to use geospatial data as a key part of the solution and specifically, any information about any role that NGSI might play in helping to link context information to the geospatial data.

In addition, the interviews were used to identify any challenges in linking NGSI with geospatial data and any solutions developed by those interviewed so that this could feed into the work of deliverable D4 within this project.

5.2 Information gathering process

The work commenced with informal interviews with the European Commission DG JRC team managing the INSPIRE initiative, Forum Virium Helsinki, Civitas-Connect and Porto Digital to gain a general overview of the key issues. Using these interviews, and internal discussions, a set of eleven questions was agreed to act as the basis for a further set of interviews, to ensure that all key issues were covered. The questions are provided in Annex A.

The interviews were transcribed using the help of an AI application and many of them were also recorded.

All the participants acknowledged the value of the work that ETSI has originated and are open to further interviews and questions, which will be a useful input to the work on deliverable ETSI GS CIM 050 [i.1].

5.3 Interviews

13 interviews were conducted, each lasting on average around one hour:

- European Commission DG JRC/INSPIRE on the general issues of cities and communities linking their geospatial data with other data.
- Overview of Swedish municipalities use of geospatial data by Tobbe Lahrin - a public sector geospatial expert since the 80 s and who has been working for the last few years on supporting Swedish municipalities around the use of IoT.
- Valencia that uses NGSI extensively and has done a lot of work on a platform that can provide two-way alignment with geospatial data.
- Porto digital (2 x) the innovation agency of the city of Porto, that is actively exploring how to integrate their NGSI-data with their GIS data.
- Civitas-Connect a German not for profit made up of 7 cities and regions and 6 municipal companies, all exclusively in the public sector that is developing a core data sharing platform on behalf of the members, which specifically aims to address aligning NGSI and OGC standards.
- Rennes - a French city that is investigating the potential role of NGSI in its data platform, with the link with geospatial data as one of the key issues.
- Forum Virium Helsinki - a city with a strong geospatial background, that is looking at how to link geospatial with other types of data to provide added insights, specifically around the use of local digital twins.
- Riga.
- Eindhoven.
- City of Brussels.
- Catalonia/Norway consortium preparing proposal for a bid for DS4SSCC pilot focusing on linking different types of data and with a strong FIWARE® and OGC background.

- A Consortium that has won a proposal starting in September 2024 3DXVERSE on developing a platform to link LDTs.

These interviews provided a great deal of information about key use cases related to geospatial data and some helpful information about the challenges that this will involve.

6 Results of interviews - Use cases

6.1 General

Based on recent research commissioned by the European Commission DG JRC, the team interviewed confirmed that all cities heavily use geospatial data for many issues. This is because cities are required to maintain much of this information by government regulations and also because they need it to manage all the assets that they own and tackle key issues such as managing traffic and the environment, for which geospatial data is vital.

However, the research showed that **this city data tends to be siloed off** and not readily available for re-use. The interviews conducted for the present document highlighted the fact that in many cities the Geospatial department **tends to manage its data separately from the data collected by other departments**.

This provides the opportunity for significant gains from leveraging geospatial data more effectively and linking it with other data to help the city tackle the key issues it faces. In this clause 6, some of the main use cases within smart cities and communities are covered for linking geospatial data with other data to gain greater insight.

The interviews made it clear that cities and communities need to use geospatial data alongside other data in order to address a number of different use cases and some of the most important of these are covered in this clause.

In looking at these use cases, it is important not just to focus on the technical issues of interoperability, but also to look more widely at how data can support the procurement of solutions and the wider business case for the investment needed in gathering and using the data. It is not enough to develop solutions that work if they cannot be implemented because of the lack of a clear business case.

So, when looking for solutions, it is useful to look at each use case, not only from the perspective of what data is needed to make it work, but also to identify what data is needed to demonstrate value for money. Most of the data needed will be common, but there is likely to be some additional requirements, the fulfilment of which would help to enrich the business case for using geospatial and other data to tackle that use case.

For instance, it is important to show that the solution is described in a way that demonstrates how it opens up the data to be used in other ways by providing some hooks that will allow solutions to other use cases to be built on more easily in the future.

6.2 Real Estate and urban infrastructure

6.2.1 Overview

In looking at use cases, the obvious place to start is real estate within the city - the buildings and their inhabitants, the roads, along with all of the urban infrastructure - as this is the first reason why cities needed to collect geospatial data.

The city needs to be able to identify where all the buildings in the city are, who owns them and who uses them. It needs to be able to identify the boundaries of parcels of land and who has rights over the use of that land.

There are many specific use cases. For instance, when procuring work to resurface a road, it is important to know the surface area of that road so as to quantify how much tarmac will be needed to cover it, and to be able to define exactly the precise length of road that needs to be resurfaced. Defining the surface area of a road is also important when it comes to putting salt on the roads during icy weather, or using snow ploughs to clear the roads, or even cleaning up roads after a major storm from mud and debris.

Then there are all the requirements of city planning to make long term plans for the city and decide where new housing can be built, where industry should be located, and where there should be commercial offices.

6.2.2 The 10-minute city

A specific and current example of the importance of geospatial data in city planning is the move towards redesigning the city to make it a 10-minute, or 15-minute city.

The aim is to increase the quality of life of the inhabitants and to become more sustainable.by making sure that all basic amenities are located within a maximum of 10 (or 15) minutes on foot or by bicycle for the city's inhabitants and users.

These might include:

- Places where citizens can interactive: schools, nurseries, sports facilities, cultural venues, health institutions, senior citizens' residences, social services, etc.
- Services of the residential economy: specialized or general food stores, non-food shops (pharmacies, post offices, cash machines, etc.).
- Places that improve the environment and the living environment: publicly accessible green spaces, playgrounds, communal gardens and allotments, recycling centres, glass recycling points, etc.
- Mobility infrastructures: railway stations, public transport stations, car or bicycle sharing stations, bicycle parking, etc.

The city's public infrastructure has therefore to be spread across the region in an efficient and well-thought-out manner (see [i.2]).

To make this work, it is not enough to identify some kind of arbitrary straight-line distance away from each service access point, but rather it is necessary to map actual routes to make sure that the services can be reached within 10 minutes, and this requires sophisticated use of geospatial data and local digital twins.

6.2.3 Underground utilities networks

Cities also need accurate records of underground pipes, cables and ducting. In Sweden the Swedish Postal Telecommunication Agency maintains accurate and detailed information about everything that is in the ground. That information is not accessible for everyone because of national security and commercial confidentiality. But this means that before any digging takes place in the city, the Agency can say where the dig can take place and where it cannot. Elsewhere, this might be the responsibility of the city or regional administration.

More generally, this is an important requirement to ensure proper maintenance. It is vital that accurate information can be maintained about the age and condition of sewers, water and gas pipes, electrical and telecommunications cabling and ducting, along with information about when they were last inspected and who is responsible to maintain them.

The challenge is that these different types of infrastructure are often managed by different agencies, some regional or national in character. But it is important that this information is all brought together so that the city can have proper oversight of the essential utilities provided to its citizens.

6.3 Dealing with disasters

Cities and communities need to be prepared to deal with disasters and this requires the gathering and use of extensive geospatial data.

A good example of the importance of this is shown by a major forest fire in Sweden that resulted in billions of Swedish Kroner worth of damage. A key reason for this was the fact that those responsible for managing it did not have the information they needed about the roads, the key sites, where people were living that need to be evacuated, and so on.

The information needed in a disaster is not what is needed in normal life. It is not important whether a road has been designed for cars or as a route for bicycles. In a disaster what is important is whether it is wide enough and robust enough to allow fire trucks or ambulances to pass.

For potential flooding from heavy rainfall or high tides, information is needed about which areas would be flooded and how quickly the water would reach them.

To better prepare for the impact of the climate crisis the Copernicus data sets are very useful, for instance to identify. the heat spots where the temperature is higher than the surrounding areas so that the causes can be identified in order to mitigate the problems as the average temperature increases over the next few years, and in order to learn how to better design urban areas in the future.

There are many other use cases that could be covered here. For instance, where the city has a database of all the trees in the city and these can be filtered in different ways, then should there be an infestation of, for instance, the processionary caterpillar that lives on oak trees, it would be easy to find out where the oak trees are located in the city to quickly respond and deal with the problem.

6.4 Mobility

Clearly mobility is one of the key use cases for cities and communities.

Here data interoperability is an important focus point because mobility is inherently in an interdisciplinary setting. There is the mobility side, that traditionally has had its own data formats and systems, and there is urban planning where there is a different set of conventions. The challenge is how to describe the urban environment so that it can be used for both simulation, which is a well-established process in mobility, and also for urban planning, which traditionally has been more about the urban geometry.

There are some steps towards this, for instance in CityGML, where the latest versions aim to address both aspects, but this is still coming very much from the geospatial side.

Then there is traffic planning; to know how traffic could be re-routed if there is an accident or if roads need to be closed for repair.

Simulations could be used for bus travel to understand how to improve the routes and timings. Similarly, simulations could be used to identify where effective cycling and walking routes could be developed.

Linking live information to online maps can support the use of city bikes and e-scooters by showing how many bikes or scooters each parking station has so that people can know where they can find a bike or e-scooter and where they can park it at the end of their journey. It can also show where there are vacant parking spaces for cars and where the nearest taxi is parked.

Geospatial data can also be used to support, for instance, visually impaired people, in navigating around the city. It can provide the blind or visually impaired person with information about everything that is of interest for them. It could warn them about obstacles in their way such as a bicycle park or an outdoor restaurant, or something that is normally not there, such as roadworks cutting across the walking route or glass on the street. Such tools can give them confidence to go out on their own and even use buses and subways.

6.5 Other use cases

Many other use cases were mentioned by the cities interviewed including the following:

- Displaying information about current and planned events at key points of interest on the online map of the city.
- Developing maps to visualize data and help citizens and decision makers understand the key issues more quickly and easily.
- Asset management.
- Environmental issues such as dust particles, noise levels, and so on.
- Supporting responses to crime.
- Tax management of building related taxes.

7 Challenges related to geospatial data for cities

7.1 Challenge of defining regions of interest

One of the challenges mentioned was those cases where it is difficult to define the regions of interest for the different datasets that need to be linked, since the detail levels can be very different. For instance, there may be a dataset from, citizen participation which includes very detailed points of interest that that people have tagged on maps to show that this particular point feels uncomfortable or that they like this particular feature. So that could be precise point data.

Then there might be aspects which are really much cruder in in terms of spatial resolution. For instance, some of the demographics data for example might be linked to postal code zones or something else that cannot be pinpointed to an individual coordinate point.

Bringing those together in a meaningful way so as not to create false observations is challenging. That has some parallels to what people have done in cartography, historically, where different scales and probabilities exist when there are fuzzy boundaries and things like that. So, there is some good experience to draw on, but the work has to be done.

7.2 The need for context to observations

The example of urban traffic counters was mentioned, which provide the city with a system that counts vehicles or pedestrians passing a certain point. But if this is to help with traffic simulation, then the point observations need to be linked to the traffic network to help understand the implications of any. For instance, to understand whether a blockage on one piece of road cuts off a very important branch that would have significant impacts across the network.

So it is important to have more context when measuring traffic in a particular point about which parts of the network does this point influence. At that particular point where the traffic flows are being measured, it is important to know where the people are coming from and going to so that alternatives routes could be identified to enable them to get to where they want to go. Without having that information, it is difficult to work out the implications of any anomalies in the measurements that are being collected.

7.3 The need to work at different scales

When for instance, mapping real estate or describing it in geospatial terms it is important to take into consideration that the real estate does not simply have one geometry connected to it. When zooming right out to say a city scale, it may be right to use a single point to represent say a building. Then, when zooming in, it might be appropriate to show a generalized border to give the approximate shape of the building or plot of land. Zooming further in, there might be a more detailed polygon or area. And at some stage, there might be a 3D model of the real estate that can describe slopes and different levels. Zooming in even further it might be necessary to define individual rooms or features.

So, when one wants to have an identity for a spatial object and connect data to it, web feature services are needed using vectors. The problem with using vectors is that there needs to be different generalization on different zoom levels. For instance, if roads are kept consistently to scale they would not be visible when zooming out. So, in most maps covering a large area, the roads are not shown in the scale that is realistic but are widened to make them visible. A road that might be 10 metres wide in reality might be shown as 100 metres or 200 metres in the zoomed-out map.

7.4 Batch integration and near real time integration

For some use cases, it is good enough to align the geospatial and other data sets on a periodic basis, say once a day. In other cases, near-real time alignment is required. For instance, changes in ownership of buildings may only need to be updated once a day, whereas indicating vacant parking spaces requires near real time updates to a map.

Near real time alignment is clearly mainly focused on information coming from sensors, but in other situations such as disasters, other information may also need to be updated in near real time. This brings the added challenge that potentially some information may normally be updated using batch processing, but might need to be updated in near real time during emergencies.

7.5 Local Digital Twins

Local Digital Twins [i.3] clearly have a strong geospatial dimension and the move towards the implementation of LDTs is a key driver for cities to see how they can better use geospatial data. However, particularly in the context of [i.3], an important aspect to consider is the social dimensions of LDTs and the need to blend in wider sets of data.

For instance, when considering topics such as vulnerability to climate change, this is a theme where there are physical phenomena that can be simulated to identify the direct impacts of climate change in the urban environment. But then there are equally important issues, such as the demographics or the vulnerability of people, in the urban setting that need to be part of such simulations. One aspect is issues such as flooding, storms, temperature and the impact on the city. On the other side it is about the demographics and how, for instance, these might be more challenging for older people to navigate through.

Given that the city has limited resources and so cannot deal with every problem, judgements have to be made regarding issues of equality and justice, and what will bring the greatest cost benefit. For instance, it is generally more important to know which is the hottest kindergarten in the city than which is the hottest warehouse.

Where there is a challenge like adapting to, or responding to climate change, geospatial data needs to be brought together with lots of other data, some of which is quantitative and some qualitative. This makes interoperability more difficult compared to a situation where, for instance, there are two different types of sensor networks that need to be integrated, but both of them are just numbers.

And the geospatial data can only have practical applications if it can properly be linked with these other types of data, to feed into models that make sense and take into account of all of the different issues.

7.6 The challenge of data models

7.6.1 Complexity

Commonly there has been an idea that one data model could be created that would cover everything related to a particular object or entity and then a data model is developed containing maybe at most 15 tables.

However, there are many instances where this does not work. Typically, to provide information about real estate, one might have a database with 120 tables covering the buildings and land, containing information about ownership, the history of previous owners, alterations, and regulatory issues. So, it is impossible to fit that information into a single data model.

The kind of approach needed is, rather than trying to get all the data on this database into a single data model, instead to focus on use cases. For any one particular use case, all 120 pieces of information would not be needed, just 3 or 4 might enable a particular issue to be dealt with.

Several different data models might therefore be needed to be developed to describe any entity or object, each focused on tackling a particular use case. The key issue is to make sure that these data models are built in a consistent way so that, when necessary, they can work together to provide a consistent description of that object through all the different use cases.

7.6.2 The need of subject experts to develop the data models

A big challenge in developing data models is that the collection of the data is a very different skill to that of understanding its significance. A city may have hundreds of data sets for very many different types of issues. So, it is important to identify how these could be correctly combined to gain meaningful insight.

For instance, when collecting data about traffic levels and air quality, it is important to first identify a subject matter expert to suggest what might correlate with what and at what levels, etc., in order to gain meaningful results. It is those experts that need to define the right fields needed for the data models used.

7.6.3 The need of a consistent approach

One other challenge is that many different departments and organizations within the city may be collecting information about the same objects and, typically, each team may use a different data model. This, of course, might be appropriate if they are tackling different use cases, but there does need to be a consistent approach, and, at the very least, there is a need for those different data models to be made public so that appropriate links can be made between them.

7.7 Identifiers

Clearly, one essential aspect when linking different data sets is to ensure that all are using common identifiers for each entity or object covered, or at least identifiers that can be mapped to each other.

A key challenge is that some data sets might use geographical coordinates to place things, while others cover buildings or addresses or objects such as lampposts. Some data might require identifiers for rooms within buildings. Some data sets might be of areas and surfaces.

So it is not simply the challenge of, say, having common identifiers for lampposts. It is actually about recognizing that there can be completely different ways to refer to the same object.

Linked to this is the fact that some data sets might refer to a building, whereas for other sets it might be the location of the entrance that is important. And that has to be addressed separately; having an identifier of the building, having an identifier for each entrance of that building and then indicating that they are connected to a specific address that also should have a unique identifier.

Another challenge is the need to match data that may not completely align, for instance regarding building geometry / addresses and cadastral parcels. Administratively they can often be matched but not all the time and this is especially true of apartment buildings.

There is also a need for semantic interoperability as different data sets might have different interpretations for what is considered a room within the building and so. A good example is that in some countries the floor of a building at ground level is called the 1st floor, whereas in others the 1st floor is used to refer to the floor above this.

Another issue is that many data sets might have a common identifier but one that is only unique within a municipality itself. So, when the set is brought into a data space containing data from several municipalities this requires the identifiers to be distinguished from each other. For instance both municipalities might have streets with common names.

Sometimes identifier systems are determined by national government, which tackles this last issue in terms of sharing information within a country, but not for sharing information across countries.

Another problem comes with issues such as air quality. It may have different neighbourhoods in a municipality and a common question is what is the air quality in this neighbourhood? However, air quality does not stop at the borders so to link quality levels to specific neighbourhoods may not be meaningful, when this will vary within and between neighbourhoods.

7.8 Issues with software

7.8.1 GIS Software

The Open Geospatial Consortium develops standards. To be able to handle geospatial data in a way that complies with OGC standards, software is needed. Cities tend to use either commercial GIS software or the QGIS solution. Sometimes PostGIS will be used alongside QGIS to handle specific issues.

The commercial solution of choice is the one provided by one of the major GIS software providers, whereas the other two are both open-source.

Although the commercial solution provides a comprehensive set of features, it is expensive and requires buy-in to the whole ecosystem. Nevertheless, it probably is the software used by most cities.

QGIS is free to use and much easier to incorporate within an open-source software environment, but it does not have some of the features of the other. The interface is not as user friendly and a lot of configuration is needed, with few plug ins available, so cities need to add any that are needed. It is not as good at dealing with complex data and 3D. In fact, because of the extra programming needed to address specific city requirements, the costs of using QGIS can mount up. It also requires more local expertise to be able to address any shortcomings.

PostGIS tends to be used alongside QGIS as it performs some functions more quickly, specifically related to databases.

Some cities use the commercial solution more or less exclusively, while others use QGIS for most things, and the commercial one just for more complex data. Some of these have a roadmap for moving to QGIS completely.

One city interviewed uses an additional commercial feature manipulation engine software, alongside the base GIS software. This is a no-code data translation and transformation tool that allows users to extract data from various sources, manipulate it as needed, and publish it in the desired format. While it is not specifically GIS, it is designed to read and write all kinds of GIS data and supports many data formats.

Both the commercial solutions and the open-source ones are designed for GIS professionals and are difficult to use by generalist data experts, so the end result is often that all the mapping is undertaken by just a few people in the municipality.

One other challenge is that sometimes the GIS professionals in a city council, while understanding how to use the software, do not necessarily have expertise in software structure and usage and may therefore not know about or be able to effectively utilize all the features of the software package they use effectively.

Another issue highlighted in the interviews is that often different departments within a city administration may use the same GIS software, but handle it differently, for instance using different data models. This results in geo-spatial data sets coming from different departments in the same city administration frequently requiring significant manual work to align them.

7.8.2 Game engines

Game engines (see https://en.wikipedia.org/wiki/List_of_game_engines) are often used within cities to develop detailed 3D digital replicas of the city. Using a game engine enables a photo realistic environment to be developed and it is easy to incorporate augmented reality applications that makes them useful for "CitiVerse" applications.

The problem with gaming engines is that they do not have to deal with different coordinate systems and different reactions and different zoom levels. They are built to create a game environment at a single scale suitable for gameplay.

However, cities and communities need digital replicas that can be used at a variety of scales. These need to be able to display detailed objects such as doors and windows, described using BIM standards. But they also need to be able to zoom out to show a neighbourhood, or city or region. And one needs to be able to maintain accurate coordinates between all of these different representations.

So, while the use of game engines can seem very attractive within local digital twins, they are not usually suitable for that purpose.

7.8.3 Mapping software

Many IoT platforms use free maps created by other users because that can provide a ready-made map. However, the challenge is that many municipalities do not use them as they need to guarantee its accuracy, and so they have to develop their own maps.

Another alternative is commercial and possibly more accurate maps that work well and people are used to. The problem is that it is cheap as long as user authentication is not needed, but as soon as users need to be authenticated to enable them to have access to the map data, then it becomes extremely expensive.

Hence, when interviewing the cities, it was clear that they use specialized software to create maps, both open-source and commercial. Most often, therefore, programmers use software like OpenLayers to develop maps as it is open source and available at no cost, even with logged in users. Some cities also use map producing tools from leading commercial vendors.

The range of options that are used to develop maps used within cities and communities complicates the process of integrating data from other sources onto maps.

8 Examples of good practice

8.1 Introduction

Our interviews have identified that many cities are aware of the challenges of using geospatial data to address use cases within smart cities and communities, and specifically of the need to integrate geospatial data with NGSI and NGSI-LD.

Two initiatives were identified that had developed useful tools to help integration between NGSI and OGC standards - Civitas Connect and the city of Valencia. Their work can usefully be built on. Eindhoven, Riga, Rennes, the city of Brussels, Forum Virium Helsinki, Porto Digital are all working hard to integrate geospatial data with other data sources in the city to help tackle city challenges, with some specifically working with NGSIv2 and NGSI-LD, They have a lot of good practice to share and would be interested in working with ETSI and others to identify practical solutions. Two consortia have either to start a project or are bidding to gain funding for one, they are both interested in exploring not only sharing their existing knowledge but also potentially piloting solutions. The Open Geospatial Consortium has also expressed an interest in exploring a potential piece of joint work on the integration of NGSI-LD and their standards.

Finally, a detailed interview was held with Tobbe Lahrin who developed a number of successful geospatial applications for cities in Sweden during the final decades of the last century and has more recently been working with Swedish municipalities on procuring IoT solutions. He is an active participant in Standards work and is Editor of the work on the IoT reference Architecture within IEC/ISO JTC1 and co-chair of the JTC1/IEC SyC Smart Cities Joint Working Group on Urban Digital Twins. He has a wealth of knowledge and experience in this area and would be glad to provide further input.

8.2 Minimal Interoperability Mechanisms

While this topic was not covered in the interviews, it is important to mention the Minimal Interoperability Mechanisms (MIMs) the development of which is managed by Open & Agile Smart Cities & Communities and the Living-in.eu initiative set up by the European Commission.

The MIMs aim to provide guidance on simple but effective methods to tackle key interoperability issues associated with sharing and reusing data. There are a set of 10 MIMs at various stages of development, each addressing one specific interoperability issue. The format, structure and role of the MIMs are described in Recommendation ITU-T Y.4505 [i.5], which, as of October 2024, is at pre-publication stage.

The development of the MIMs began in 2015 and the first three MIMs have been extensively taken up by cities and communities. All of the MIMs are now being reviewed to ensure that they comply with Recommendation ITU-T Y.4505 [i.5].

MIM7 focuses on geospatial data. The objective of this MIM is:

"*To enable cities and communities to easily integrate data about spatial assets such as streetlights, buildings, and streets with spatio-temporal data from sensors, along with other data sources that can provide helpful context information to the geospatial data, and make the data interoperable within, and between cities and communities.*

"This integration should be made possible across technologies and vendors."

In order to fulfil this objective, MIM7 requires that geospatial data sets comply with standards from OGC and BuildingSmart International.

MIM7 is continuing to be developed and one of the capabilities on which further work is being done is: "Cities and communities can integrate geospatial data with other data that can provide further information about the context." There is clearly value in ISG CIM working closely with the MIM7 working group, specifically because the European Commission is discussing with ETSI their potential role in bringing the individual MIMs into European standards.

8.3 Civitas Connect

Civitas-Connect is a German not-for-profit made up of 7 cities and regions and 6 municipal companies, all exclusively in the public sector, that is developing a core data sharing platform on behalf of the members. This is called CIVITAS/CORE and the plan is that it will enable cities, regions and municipal companies to effectively manage any kind of data.

CIVITAS/CORE integrates well with digital infrastructures in urban environments and is designed to be extendable and adaptable to the specific needs of any city or region. Thus, it is the base - in their words: the "CORE" - that provides everything required to manage data in urban environments, which can then be extended to a comprehensive urban data platform that is customized to a specific city or region.

Following the principle "Public Money - Public Code", CIVITAS/CORE is an open-source software available for everyone, thereby supporting scaling effects to be quickly and widely adapted. It comes without operator dependency - any public or private entity can operate the software itself. Because it is open source, any operator has full transparency and control about the software which supports finding and fixing security issues early on.

CIVITAS/CORE reuses many popular open-source software technologies and combines them in a "clever" way. The following architecture provides an overview.

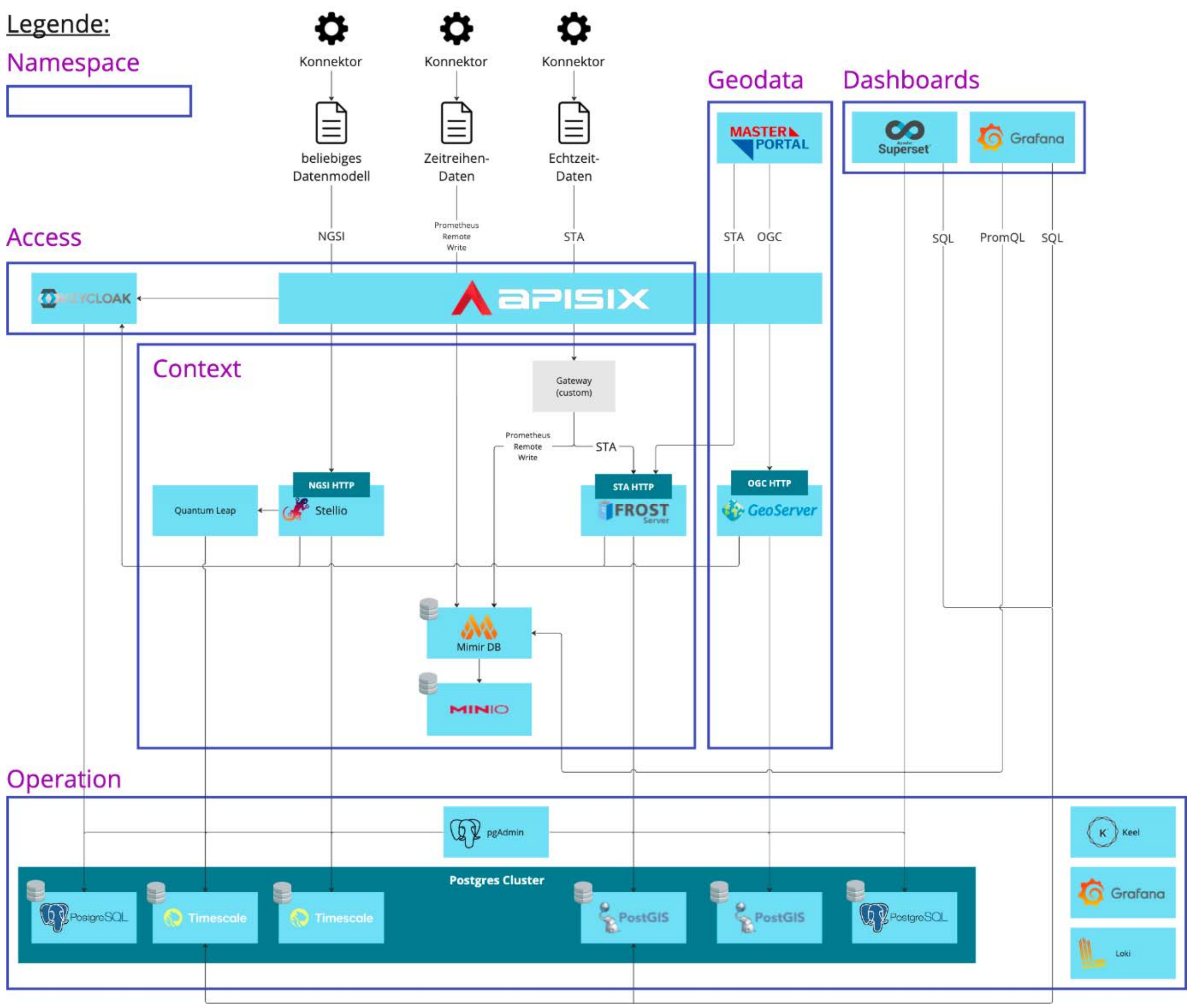

Figure 2: Civitas Core city platform

CIVITAS/CORE provides four external APIs:

- OGC SensorThingsAPI by FROST Server.
- ETSI NGSI-LD by Stellio Context Broker.
- OGC Standard APIs provided by Geoserver.
- Prometheus Remote Write by MimirDB.

Civitas Connect has developed a proof of concept to convert a NGSI-LD data structure into the SensorThings API data structure and back while storing the data only once. With that they aim to show that the STA and NGSI standards can interoperate without redundant data storing (see [i.4]).

8.4 Valencia

The city has developed a Smart City Platform that is largely built on FIWARE® Components. It uses NGSIv2 rather than NGSI-LD because it has been told that NGSI-LD is not backward compatible and that therefore to move to NGSI-LD would mean changing many subscriptions in a production environment. They will change to NGSI-LD once this issue is dealt with.

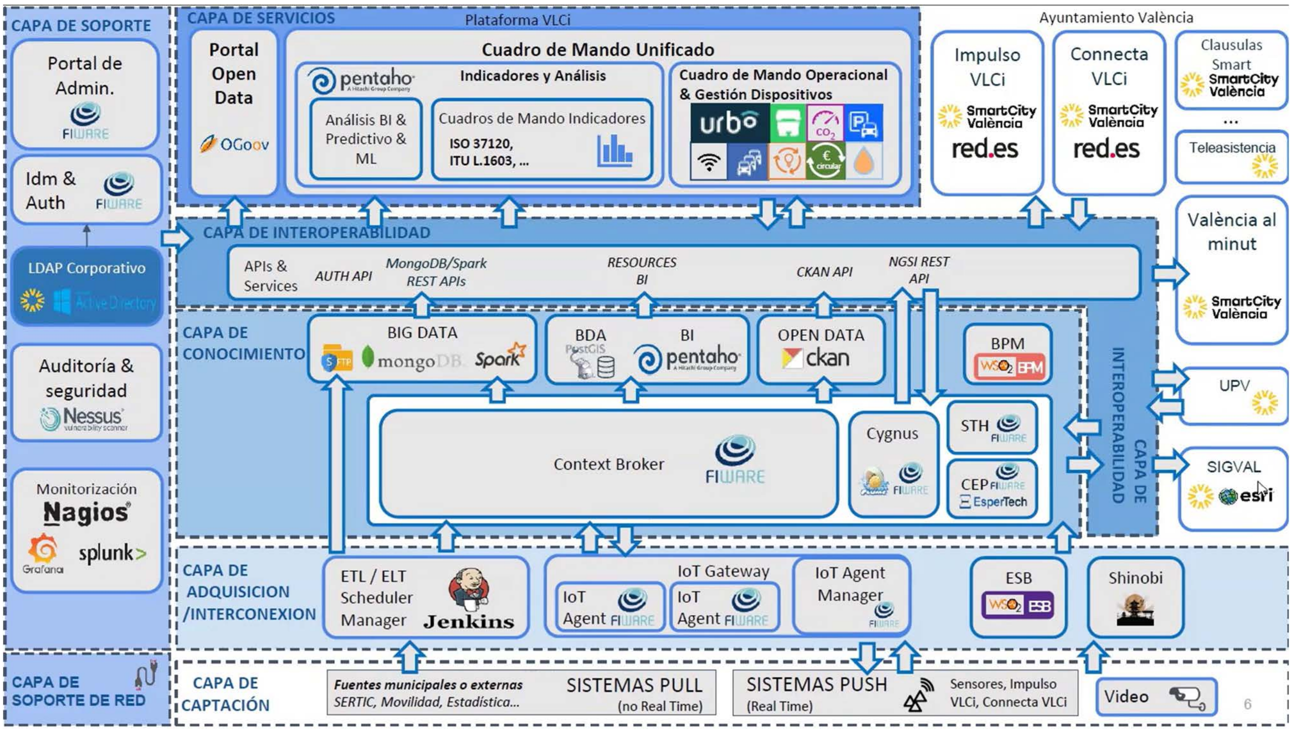

Figure 3: Valencia's data platform

Valencia uses commercial GIS exclusively for handling geospatial data. It has developed two bi-directional ways to link geospatial data with NGSI managed data using a publish subscribe mechanism.

8.5 Other cities and projects

The other interviewees are all actively involved in practical implementations of geospatial data in delivering on city objectives.

Porto Digital is the innovation agency of the city of Porto. It uses NGSIv2 extensively and is slowly moving towards NGSI-LD. It is in the process of running a series of workshops with the geospatial department of Porto city council to identify how to integrate NGSI with the geospatial data and the city's geoportal.

Forum Virum Helsinki is the innovation agency of the city of Helsinki. The head of data for the city council suggested the person that was interviewed within Forum Virium as the key expert on geospatial matters, both within Forum Virum and also for the city council.

The city of Brussels smart city team has recently started work with the geospatial department specifically around the development of a Local Digital Twin to underpin the move to a 10-minute city. The Geospatial department is in the process of moving from commercial GIS to QGIS because of a commitment to open source. The city does use NGSI-LD and the need to align this with geospatial data is well understood. It was possible to have a meeting with the smart city team, the key people within the IT department and the head of the geospatial department.

Eindhoven has been one of the pioneering cities in the use of data to support citizen first services. The head of the geospatial department and a key figure in the city's data innovation work provided a great deal of practical information in our interview.

Similarly, with the cities of Rennes and Riga it was possible to interview key people from the overall data strategy and the geospatial departments in the city administration.

9 Overall priorities

9.1 Introduction

This clause highlights the key issues from interviews which will need to be addressed in any further development of NGSI-LD to support integration with geospatial data and provides suggestions for the overall priorities to be addressed in ETSI GS CIM 050 [i.1].

9.2 The use of NGSI, NGSI v2 and LD

Interviews indicated that it is likely that many cities using NGSI as part of their data management are still mainly using NGSIv2 and not NGSI-LD. This is because of the perceived lack of backward compatibility of NGSI-LD, requiring new skills and also the challenge of updating many subscriptions in an production environment.

As part of any work on updating NGSI to better address geospatial data, consideration might be given to enhancing NGSI v2, along with work on NGSI-LD.

More generally, ISG CIM might look to further address any issues related to the upgrade path from NGSI v2 to NGSI-LD, possibly by working with those cities that are in the process of upgrading, or have already done so, to identify the challenges they faced, what strategies they adopted to help, and the value gained from the upgrade.

9.3 Aligning data sets

Normally, when integrating geospatial data with other data sets, such as those that are NGSI-LD compliant, it is not necessary to integrate the two data sets completely but rather to update between the two on a periodic basis. One option is simply updating changes from one data set to the other on a near real time basis. Alternatively, batch processing can be used to align the data sets, say, once a day. Near real time updates of changes is more resource intensive, but is needed for use cases such as updating maps to show vacant parking spaces or availability of cycles or e-scooters for rent. For other use cases such as updating ownership of buildings etc., batch processing is good enough.

Both of these two options need to be addressed in developing solutions for aligning NGSI-LD and geospatial data and consideration also needs to be given to the fact that synchronization may need to happen in two directions, or potentially to be two way.

9.4 Domain Driven Design

As has been mentioned, often different departments in a city administration, or different organizations in different domains that wish to share data, might handle the data differently, even when using the same software. This specifically relates to the use of different data models or ontologies. This is linked to the role of subject matter experts referred to in clause 7.6.2.

This does relate to NGSI-LD, specifically to work going on within ISG CIM on the need for management of complex service execution in NGSI-LD systems.

The use of different ontologies and different data models within different domains is to be expected as different domains address very different areas of concern, with different concepts and terminology for objects and processes that they might have in common. The challenge comes when data needs to be brought together from the different domains to address new use cases. It clearly does not make sense to force all domains to use precisely the same data models and ontologies. Rather guidelines are needed to support consistency between these different ontologies and models - as is the case, for instance, with SAREF - to facilitate mapping between them.

This is where established data sharing mechanisms such as Date Driven Design, and Data Mesh might help provide useful methodologies and processes.

9.5 Addressing the issue of defining regions of interest

Clause 7.1 covered the challenge of defining regions of interest. Potentially, geofencing might have a role in addressing this. It might be worth considering the opportunity to model and enrich the Zone concept in the cross-domain ontology.

9.6 Minimal Interoperability Mechanisms

The Minimal Interoperability Mechanisms are aiming to address issues of interoperability, with MIM7 in particular focusing on the need to link geospatial data with other data that provides information about the context. Members of ISG CIM have joined some of the MIM7 Working Group meetings in an individual capacity and this has proved very helpful.

However, in order to share the work and ensure consistency, ISG CIM might consider developing a more formal relationship with the MIM7 working group. It may be noted that one of the members of the MIM7 working group attends as a formal representative of OGC.

10 Conclusions

The work of interviewing cities indicated how timely this piece of work is, in that many cities are grappling with the challenges of using geospatial data to address city use cases and specifically in many cases to identify how to align NGSI with geospatial standards.

The interviewed cities and projects have indicated that they are interested to continue to keep in touch with developments and to contribute as they are able. Potentially they could form the core of a community of cities working together to address the common requirements. This might link with the potential role ETSI might play in standardizing the Minimal Interoperability Mechanisms.

It is suggested that, once deliverable ETSI GS CIM 050 [i.1] is produced, ETSI might wish to host a workshop to review the conclusions of the two deliverables (the present document and ETSI GS CIM 050 [i.1]) and provide further comment.

After discussion with OGC, who are also looking at how to better integrate OGC standards within data ecosystems used by cities and have developed a Proof of Concept relating to Smart Data Models. They have indicated that they would be interested in at least an initial discussion with ETSI about potential collaboration in this area.

Annex A: Interview Questions

For the interviews, the following questions were used:

1) What are the most frequent or important uses for which you need a geographic information system? Mobility, solid waste management, city planning, flood analytics and management, street light management, etc.?

2) How far do you use OGC standards in your GIS system?

3) Which GIS software are you using? Commercial GIS, open-source (QGIS, etc.)? What are the shortcomings (if any) of your current GIS platforms?

4) Do you use CAD tools such as those from Bentley or Autodesk?

5) What are some of the non-geospatial software systems used within your city? Specifically, are FIWARE® and/or NGSI-LD-based software components in use?

6) Do certain use cases require a certain level of interoperability between geographic information systems and other software (FIWARE®, CAD, etc.)? If so, which ones? Can you briefly describe them?

7) Does it happen that the same real-world object, such as a building or a traffic light, is represented by different objects or entities in different systems? For example, a building represented as a feature in a geographic information system and as an entity in a smart data model. In such a case, how do you make sure they represent the same real-world object?

8) How do you handle sensors, cameras, and other smart objects (IoT)? Which framework/standard are you using? OGC IoT API, FIWARE® IoT agent, etc.?

9) Are you using AI or planning to do so? If yes for which use cases?

10) What are the main unfulfilled needs your software platform do not meet yet?

11) Can you think of one or two questions we didn't ask that we could have?

History

Document history		
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