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Interoperability and the Minimal Interoperability Mechanisms

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Abstract

The chapter sets the context of local data sharing ecosystems, where data from many different agencies can be brought together to enable the city to be managed in a more holistic way. It points out that this requires technical, information, and organisational interoperability and provides a list of some of the specific areas where interoperability is needed in such an ecosystem. It then places this within the European Policy Context.

The concept of minimal interoperability is then dealt with as a way of enabling small- and medium-sized cities and communities to put in place "good enough" interoperability mechanisms to enable effective data sharing without requiring excessive time or resources to implement. The chapter closes by reviewing the minimal interoperability mechanisms being developed by Open & Agile Smart Cities that are incorporated within the Living-in.EU initiative.

7.1 The Context – The Local Data Sharing Ecosystem

The people and businesses located in the city are served by a variety of different systems including electricity, water, gas and other utilities, communications, transport and logistics, education, health, and shopping and commerce. All these systems interact with each other, all of them generate data, and all of them require good data to work well.

We can define a smart city as one where increasing amounts of useful data about the city are collected and used by the public administration, by business, and by the citizen, to help the city work better.

A local data sharing ecosystem is a way of describing what is needed to allow the data being gathered by many different agencies within the city to be brought together in a carefully managed way, to provide comprehensive understanding of what is going on in the city, to allow much better city management, and to support citizens in managing their lives more effectively.

This requires interoperability – ensuring that all organisations and systems providing the data follow common standards and protocols. Having many cities around the world following those same interoperable standards and protocols will facilitate the development of a global market in the products and services that utilise and exploit city data.

7.2 Interoperability

ITU defines interoperability as: the ability of two or more systems or applications to exchange information and to mutually use the information that has been exchanged.[1]

Expanding on this, the GridWise Architecture Council[2] considers that interoperability incorporates the following four characteristics:[3]

1. exchange of meaningful, actionable information between two or more systems across organisational boundaries;
2. a shared understanding of the exchanged information;
3. an agreed expectation for the response to the information exchange;
4. a requisite quality of service: reliability, fidelity, and security.

Interoperability is not just about solving different categories of technical issues. For the information to be exchanged and used, the systems involved need to use consistent mechanisms across a number of informational and organisational categories.

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[1] ITU-T Recommendation Y.101 Global Information Infrastructure terminology: Terms and definitions

[2] The GridWise® Architecture Council (GWAC) was formed by the U.S. Department of Energy to promote and enable interoperability among the many entities that interact with the nation's electric power system.

[3] See: https://gridwiseac.org/pdfs/interopframework_v1_1.pdf

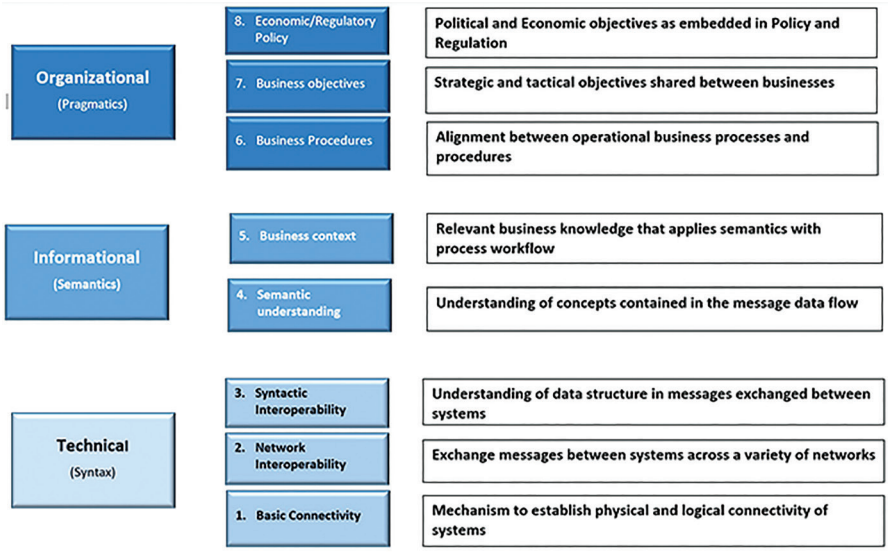

Figure 7.1 Interoperability framework categories.

These different categories can be illustrated by Figure 7.1 which is based on one developed by the GridWise Architecture Council.

As an example, for two organisations to be able to share data relating to individual persons, they both need to comply with a common legal and regulatory framework, such as the European GDPR. In many cases, ensuring interoperability within the organisational and informational categories is more difficult that within the technical ones.

Within local data sharing ecosystems, some of the key organisational and informational issues that need to be handled in a consistent and interoperable way, by all the different data sharing organisations, include:

- knowledge and context information exchange;
- use of consistent data models;
- rules of access and use for data and services;
- protection of rights (personal data, privacy, dignity, equality, etc.);
- transparency in automated decision-making (societal governance of all technology use and deployment);
- security (systems and society);
- management of location data;

- common societal objectives with measurable outcomes towards those objectives;
- interoperability of complex data models, allowing more efficient analytics and impactful exchange of expertise;
- the use of common resource management frameworks.

We will pick up some of these in more detail in the section on minimal interoperability mechanisms.

7.3 The European Policy Context

Interoperable Europe is a new initiative of the European Commission for a reinforced interoperability policy in the public sector. It evolved out of the ISA² funding programme of the European Union that supported the development of digital solutions to enable public administrations, businesses, and citizens in Europe to benefit from interoperable cross-border and cross-sector public services. That programme finished at the end of December 2020.

The issue, of course, is still not solved, and so the European Commission and its partners in public administrations across Europe are now working under the label of Interoperable Europe to continue to enhance interoperability to unlock the potential of data use and reuse for improved public services.

A recent study by the European Commission's Joint Research Centre (JRC) states that improved interoperability could lead to a reduction in the time citizens spend every year with the administration by 25%. This results in time savings of 24 million hours (about 2738 years) and monetary savings in the order of EUR 543 million per year. For business, the savings could reach up to EUR 568 billion annually.

Interoperable Europe will lead the process of achieving these goals and creating a reinforced interoperability policy that will work for everyone. It is committed to introducing a new cooperative Interoperability Policy Directive for Europe that will transform the public administrations and help them in their digital transformation. The initiative is supported by the Digital Europe Programme.

As part of this wider push for interoperability, the Proposal for a European Interoperability Framework for Smart Cities and Communities (EIF4SCC)[4] was published in May 2021. The aim is to focus on the specific

[4] https://op.europa.eu/en/publication-detail/-/publication/f69284c4-eacb-11eb-93a8-01aa75ed71a1/language-en

needs and opportunities that interoperability provides in the local context. The proposal is being discussed through the Living-in.EU community and other forums, with a view to its adoption as an official Commission document, based on users' and stakeholders' feedback.

The proposal provides 30 recommendations, along with many helpful case studies, relevant to the development of interoperable local data sharing ecosystems. It is worth highlighting some of these recommendations here.

Recommendation 12 is to "Set-up or consolidate interoperable local data ecosystem(s) that integrate and reuse data in cities and communities by stakeholders, and promotes open standards and open technical specifications, APIs and data models to provide a holistic view of the information. This aims to support the decision-making process and to foster innovation and citizen engagement".

Recommendation 14 is to "Reuse and share solutions, data, tools and services by cooperating with different stakeholders in the design, development, implementation and monitoring phases of service provision at local, regional, national and European levels".

The reasoning behind Recommendation 14 is the need to acknowledge the role of non-public administration actors in service provision in the context of Smart Cities and Communities. As a substantial amount of data and information being generated in the city is out of the hands of public administrations, the governance of any data sharing ecosystem must take a broader view and look beyond the public administration itself.

Recommendation 24 is to "Create more horizontal services towards local data ecosystems, to overcome silos within different domains, by encouraging collaboration and engagement among inhabitants, business, visitors, organisations and city/community administrators".

This points to the importance of making sure that the local data sharing ecosystem is used to support a much more holistic way of managing city services. It needs to move from simply being about using data sharing to improve the way the individual silos are managed, to one where the data is used to highlight new ways of delivering those services in ways that are much more focused around the needs of the citizen rather than on the structures and priorities of the individual departments and municipally owned companies. This points to the key role of the organisational areas of interoperability.

The European Commission recognises that while urban and rural communities in Europe are advancing in their digital transformations, they are not all at the same level. Some have already moved towards an integrated cross-sector approach to exploit the strengths of advanced digital technologies such as digital twins, local data ecosystems, AI, advanced data analytics,

high performance computing, and cloud computing. Others have started to invest in their digital transformation but need to accelerate. A third group of communities are at an early stage or have not started at all.

The Digital Agenda addresses all three groups, reinforcing the European capacity for the deployment and scale-up of AI-powered digital twins and enabling local data ecosystems in a large number of European cities and communities including the EU outermost regions and other economically disadvantaged regions.

To make this happen, the Commission has set up the Living-in.EU initiative. The signatories of the "Living-in.eu Declaration"[5] have set ambitious goals to accelerate their digital and green transition. They have agreed on a set of specifications and requirements that should enable interoperability and form the basis of their local data ecosystems and (in the next phase) local digital twins. These are the minimal interoperability mechanisms or MIMs.

7.4 Minimal Interoperability Mechanisms

As we have seen, interoperability enabled by common standards and requirements is a key part of enabling a local data sharing ecosystem.

Minimal interoperability is defined by the ITU as:[6] "The minimal sufficient degree needed to meet a certain requirement for data sharing, use and reuse. NOTE – This is an approach to build a set of modular mechanisms, including information models, across multiple domains, locations and events".

Minimal interoperability mechanisms are the minimal but sufficient capabilities needed to achieve interoperability of data, systems, and services between buyers, suppliers, and regulators across governance levels around the world. By basing the mechanisms on an inclusive list of baselines and references, they can take account of the different backgrounds of cities and communities and allow cities to achieve interoperability based on a minimal common ground.

Implementation can be different as long as crucial interoperability points in any given technical architecture use the same interoperability mechanisms. Each MIM can further define a hierarchy of levels of interoperability based on sectorial needs or the need for tighter integration. The MIMs are vendor neutral and technology agnostic, enabling anybody to use them and integrate

[5] https://www.living-in.eu/

[6] FG-DPM Technical Specification D0.1 Data Processing and Management for IoT and Smart Cities and Communities: Vocabulary [b-FG-DPM TS D0.1]

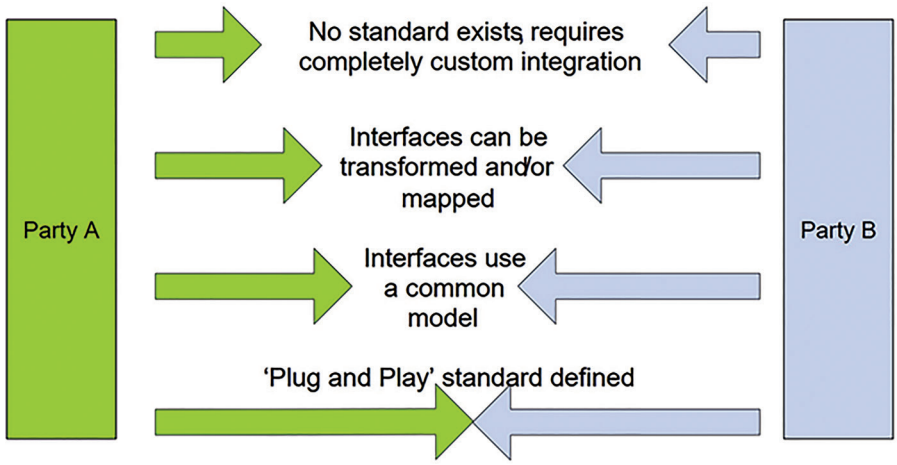

Figure 7.2 Distance to integrate.

them in and between existing systems and offerings, complementing existing standards and technologies.

Minimal interoperability mechanisms reflect the fact that different levels of standards can enable different levels of interoperability, as illustrated in Figure 7.2. Full compliance with detailed and well-designed standards can enable "plug and play" where the different components can be automatically configured to work together merely by "plugging them in" to each other. However, standards-based mechanisms that are not quite so rigorous can still play a major role in supporting interoperability as the following diagram from the GridWise Interoperability Framework illustrates.

The reason why MIMs are necessary is that there are many guidelines and frameworks covering different areas of concern that need to be put in place to enable a fully functional data-sharing ecosystem for smart cities and communities. While this can be managed effectively by larger and well-resourced cities and communities, most small- and medium-sized cities find the complete implementation of all the standards and frameworks a complicated and daunting task.

The MIMs are minimal to ensure no unnecessary complexity or time-to-implement, with the aim that the cost to implement (staff time, software, and hardware) will be affordable by small- and medium-sized cities and cities with limited resources.

MIMs are simple and transparent mechanisms, ready to use in any smart city or community, regardless of size or capacity, even to the national level, global regional level, or globally. The interoperability points assure

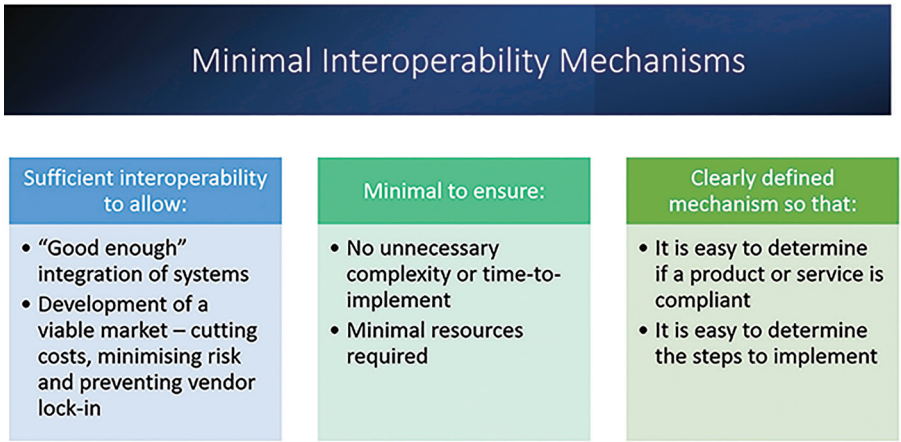

Figure 7.3 Minimum interoperability mechanisms.

the replicability of the solutions built on top of an open platform, as these are decoupled from the specific technological implementations and deployment of the architectural components. Figure 7.3 summarises these minimum interoperability mechanisms.

Essentially, MIMs provide simple, straightforward ways for a city to implement the essential aspects of what is needed to support interoperability within a local data sharing ecosystem. The aim of defining these is to enable the digital capabilities of any city or community to be based on a firm, controllable foundation. By embedding them within a city data platform and data architecture, all stakeholders can be sure that they have the data management and processing capabilities and the interoperability needed.

There are three different types of MIMs, each of which focuses on delivering the minimal but sufficient level of interoperability needed to enable an effective data sharing ecosystem.

1. Where there are existing authoritative standards, MIMs point to their core requirements to enable cities and communities to see immediate benefit in developing the local data ecosystem.

2. Where there are several standards that cover the same ground, the aim will be to identify the lowest common denominator (or the Pivotal Point of Interoperability) that will make it easy to link products and services that comply with those different sets of standards. Pivotal Points of Interoperability is a concept defined by the US National

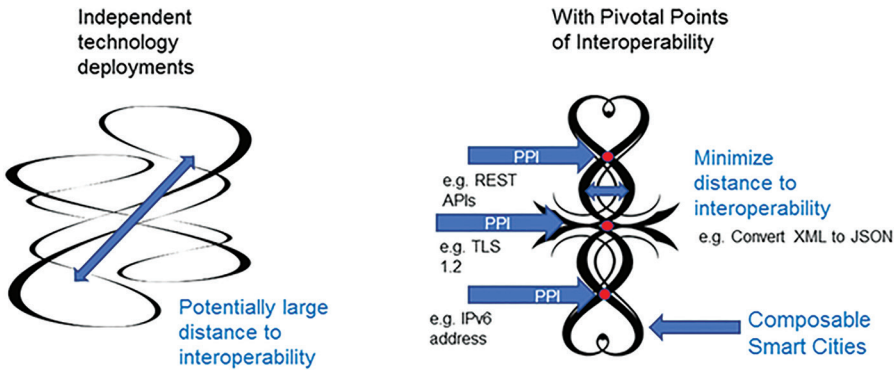

Figure 7.4 NIST pivotal points of interoperability.

Institute of Standards and Technology and used as the basis for the internationally developed IOT Enabled Smart City Framework[7] that NIST facilitated, as illustrated in Figure 7.4.

3. Where there are no existing standards, then MIMs can be developed in partnership with cities and city stakeholders that can act as minimum viable (standards) products. These can then be used as the basis for developing more detailed and comprehensive standards by Standards Development Organisations.

The idea of MIMs has gained widespread support and is included as recommendations in national guidelines, including the Danish Guide to Sustainable Digital Transformation.[8]

ITU Study Group 20 has started the process to define and describe the minimal interoperability mechanism (MIM) approach to developing requirements related to interoperability in local data ecosystems in smart and sustainable cities and communities so that they will be established formally within international standardisation. The work is to:

- provide a definition and common format for the MIMs to provide them with an established role in the standards world;

[7] NIST IES city framework https://s3.amazonaws.com/nist-sgcps/smartcityframework/files/ies-city_framework/IES-CityFramework_Version_1_0_20180930.pdf

[8] Danish Guide to Sustainable Digital Transformation – DS/INF 176:2021 (2021), Danish Standards. Available online: https://webshop.ds.dk/en/standard/M346207/ds-inf-176-2021

- provide a framework to enable MIMs to be developed in a consistent way;
- review the scope of the set of MIMs needed to enable the development of a local data sharing ecosystem, identify any others needed, and provide a process to agree and scope out any further MIMs that may become needed in the future.

7.5 The Individual MIMs

Open & Agile Smart Cities – a network of 168 cities in over 30 countries – is developing a set of 10 MIMs with the aim of covering the full set of requirements to put in place an effective local data sharing ecosystem.[9] Table 7.1 lists them.

Of course, this list may be added to later to cover any gaps that are identified. The process of making sure the full list is covered is underway. That is important as all the MIMs have dependencies on some of the other ones, and having the full list will enable those links to be put in place.

MIMs 1, 2, and 3 are already at a good level of maturity and are being widely specified by cities in procurements, while MIMs 4, 5, and 7 are under development and plans are in place to develop the remaining MIMs.

7.5.1 MIM1 context information management

IoT data provides near real-time information about what is happening in the city and the opportunity to analyse historic IoT data to detect patterns and help identify the causes of problems and how best to tackle them. However, IoT data on its own is not enough.

Air quality data from IoT sensors is itself just a stream of numbers. To make sense of that data, we need to know, for instance, that one sensor is near a busy road, another is in a quiet residential neighbourhood, and another is near a factory. We also need to know what levels of pollution are dangerous, so that warnings can automatically be triggered.

Similarly, information about timings of the data from the sensors needs to be linked with, for instance, information about the weather at that time, or the season of the year, or any event that happened at a specific time that might have had an impact on the readings of the sensors.

[9] See https://mims.oascities.org

Table 7.1 MIMs 1-10.

MIM	Name	Function
MIM1	Context Information Management	Manages the context information coming from Internet of Things (IoT) devices and other public and private data sources, providing cross cutting context data and access through a uniform interface. It therefore ensures comprehensive and integrated access, use, sharing, and management of data across different solutions and purposes. The ETSI standard NGSI-LD is the recommended specification to achieve this.
MIM2	Shared Data Models	Ensures that the datasets in a local data ecosystem use precisely the same machine-readable definitions for key terms to enable datasets to be linked with other sets that add important context information.
MIM3	Ecosystem Transactions Management	Provides functionalities to enable effective matchmaking of urban IoT data sources from providers with respective data consumers, to facilitate trusted exploitation of such data based on enforceable data usage agreements and to secure value flow between these stakeholders.
MIM4	Personal Data Management	Will provide guidance regarding what solutions cities can use to allow citizens/users to control which datasets/ attributes they want to share with solution, application, or service providers under transparent circumstances, enabling trust between the different parties.
MIM5	Fair Artificial Intelligence	Will provide tools to cities so that they can have confidence that the AI and the models they use, as well as the goals the AI is programmed to achieve, are fair and transparent, and that they use data from the local digital ecosystem in a fair and transparent way.
MIM6	Security Management	For data to be used in the data ecosystem, it may often need to go through a complex path between where it is generated and where it is finally used. At every stage in that process, it is vulnerable to attack and proper systems need to be put in place to address this. MIM6 will provide cities with the tool to do this.
MIM7	Geospatial Information Management	Will enable cities needed to use sophisticated geospatial data, for instance in 3D modelling and in locating spaces within buildings. In this way, it will enhance the geospatial data handling abilities covered by MIMs 1 and 2.
MIM8	Ecosystem Indicator Management	Will develop consistent measures of the ability of different cities to provide a healthy and effective ecosystem that nourishes digital transformation and supports interoperability of data, systems, and services. This will allow cities to assess their performance against these measures. It will also support the benchmarking of results and practices among comparable peer cities.
MIM9	Data Analytics Management	Will aim to make complex data models interoperable, allowing more efficient analytics and impactful exchange of expertise, to allow cities to leverage each other's successes in data analytics.
MIM10	Resource Impact Assessment	Will aim to develop interoperable capabilities for management and assessment of scarcity and resources related to people, nature, and investment.

So, other data is needed to make IoT data useful. We need context data to make sense of the IoT data to support real-time management of the city – to understand what actions to take as a result of the information from the IoT sensors.

Context data also enables the city to analyse historic data – to understand causes of variations and what issues need to be tackled in longer term in order to deal with any problems. It also allows the city to review potential options for how to tackle those issues so that it can know what different solutions are practical and implementable.

MIM1 points to a tried and tested way to manage context information using the ETSI NGSI-LD standard. This requires context information to be structured around entities that have properties and relationships to other entities. To do this, it requires data models to be described using the Resource Description Framework (RDF) methodology, Resource Description Framework Schema (RDFS), and Web Ontology Language (OWL).

NGSI-LD then describes the APIs needed to link the context data appropriately with the relevant datasets.

7.5.2 MIM2 shared data models

To be able to link the context information to the correct part of any dataset, it is important that the datasets concerned use precisely the same definitions for key terms. For instance, if the one dataset defines "children" as people aged between 5 and 15 and the other dataset defines children as people between the ages of 2 and 12, then a great deal of inaccuracy would result by combining them.

More fundamentally, to enable datasets to be combined automatically, the terms used in each dataset need to be defined in machine readable terms so that the APIs can "understand" how to handle them. Data models are machine readable definitions of key terms.

Finally, the data models need to be in a format that allows the context management API to enable apps to link the context data to the appropriate cells in the original dataset – in other words, they need to comply with the requirements set by NGSI-LD.

7.5.3 MIM3 finding and using the data

MIM3 is the management layer that allows stakeholders:

- to provide data along with relevant information about its content and quality and any terms and conditions for use;

- to provide data processing services along with relevant information and terms and conditions for using the services;
- to find and access the data and data processing services and other services they need and to be able to gain relevant insights into what those data streams/data processing services/data applications consist of and how valuable they can be.

There are various ways to realise this management layer. A standardised way of doing so is provided by TM Forum and Fiware that have created an API suite of specifications for digital marketplaces, named the Business API Ecosystem.[10]

7.5.4 MIM4 personal data management

Personal data management means providing clear and easy usable means for citizens/users to control which datasets/attributes they want to share with solution, application, or service providers under transparent circumstances, enabling trust between the different parties.

Citizens should be able to identify themselves with an ID of their choosing and be able to transparently (dis)allow the service providers to access their data and control the granularity of the access (full, anonymously). They should be able to give permission for applications to access the relevant attributes about them that will enable the right decisions to be made about their eligibility for benefits or the most appropriate treatment for any health conditions and to ensure their control over content that they have created, while avoiding the need to link that data with their personal identity.

MIM4 is dealt with in detail in Chapter 9.

7.5.5 MIM5 fair and transparent AI

The aim of setting up a local digital ecosystem is to bring together information from many areas of city life to help ensure that the city can be managed more effectively and more focused around the needs of the citizen.

AI and algorithms will have a key role in making sense of that data and some of those algorithms will be decision-making. It is therefore vital that the algorithms that use that data are fair and transparent and that they use appropriate data from the data ecosystem appropriately to make decisions.

[10] https://github.com/FIWARE-TMForum/Business-API-Ecosystem

Cities need to be able to test whether products and services they are procuring are fair, trustworthy, and transparent and to ensure the appropriateness and accuracy of data used both in training the algorithmic systems as well as used by those systems in decision-making.

MIM5 will provide the technical capabilities required to check that the algorithmic systems offered by suppliers comply with the requirements for fairness, trustworthiness, and transparency through identifying or developing a relevant set of APIs.

7.5.6 MIM7 geospatial information management

MIM7 aims to provide minimal interoperability mechanisms related to geo-temporal data. However, there are many existing geo-temporal data standards that are of relevance to cities and to propose the full list would not be compatible with the concept of MIMs. MIM7 is therefore being developed as a number of parts.

The discovery, querying, retrieval, visualisation, and editing of geospatial information based on location and temporal criteria can be achieved through open standard formats, protocols, and preferably through the use of standardised API interfaces. Integrating context information with geospatial information can be enabled by the context management API and geospatial management API through common data information models defined in the MIM2 data models.

The minimal requirements to be included in MIM7 will enable access to the data that is necessary to enable the above to be done.

7.6 MIMs Plus

The European Commission is supporting the development of a specifically European version of the MIMs known as MIMs Plus to help fulfil the aspirations captured in the Living-in.EU declaration.[11] MIMs Plus is based on the existing minimal interoperability mechanisms plus some additional fundamental building blocks – hence the name: MIMs Plus.[12] An operational guidance paper is also being developed with practical guidance on how the specifications captured in the MIMs can be used in practice.

[11] https://www.living-in.eu/declaration

[12] Latest version available at https://www.living-in.eu/mimsplus

MIMs are aimed at providing consistent global processes to enable a global market, while MIMs Plus is aimed at setting these in the European Policy landscape. For the time being, the only difference is that the MIMs Plus is described in a document that sets them in that policy context. However, at some stage, there may need to be somewhat different technical specifications – for instance, when the European Digital Identity Framework and Digital Wallet are implemented, this will impact on MIM4 personal data management and the technical requirements for MIM4 in Europe will need to be slightly different to the global requirements.