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Benchmarking the role of the Public Sector and Location Intelligence in Smart Spaces

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Contents

Foreword

The Directorate Growth and Innovation of the Joint Research Centre of the European Commission, based in Seville (Spain), is closely involved in creating a strong and resilient Economic and Monetary Union, ensuring stable financial markets, as well as strengthening and deepening the Single Market including the Digital Single Market.

The mission of the Digital Economy Unit (B6), based in Seville (Spain) and in Ispra (Italy), is to provide quantitative and qualitative socio-economic research in support to the Digital Economy, Digital Living and Digital Society. As part of its activities, the Digital Economy Unit is leading a flagship project in the area of Digital Transformation and Artificial Intelligence (DT&AI), with the objective to analyse the profound changes taking place in the economy and society as a result of the uptake and integration of digital technologies in every aspect of human life.

In particular, the DT&AI research, initiated in 2018, also has the aim to address the impact of digital transformation on government, where the Digital Economy Unit, in cooperation with other services of the European Commission, is co-ordinating the *"European Location Interoperability Solutions for e-Government (ELISE)*", Action 4.1 of the ISA^2 Programme, adopted with Decision 2015/2240 of 25.11.2015.

The ISA^2 and its predecessor the ISA programmes have given a strong stimulus to promoting and supporting better interoperability in European digital public services over the last ten years, echoing and amplifying the steps being taken in Member States. The many different aspects of interoperability are embedded in the principles and levels of the European interoperability framework (EIF). While interoperability factors are recognised as beneficial, understanding the contribution of interoperability to benefits can be difficult, measuring that contribution even more so.

As the ISA^2 programme draws to a close and transition is made to support Europe's new digital strategy, 'Europe Fit for the Digital Age', an impact assessment of the programme is being undertaken and proposals considered for a future interoperability strategy and an EIF that can contribute to achieving the targets set for Europe's Digital Decade to 2030.

Another key element of the EU's digital strategy, the European data strategy envisages setting up a series of demand-driven common European data spaces supported by a federated cloud infrastructure in thematic policy areas such as health, mobility and environment, with a "High Impact Project" planned from 2021-27. To support this, the Data Governance Act aims to foster the availability of data by increasing trust in data intermediaries and by strengthening data-sharing mechanisms for data voluntarily made available by public administrations, businesses, individuals and researchers.

Geospatial data and technology will have a key role to play in the implementation of a series of cloud-hosted European data spaces planned as part of the EU data strategy, in particular – but not only – to support the Green Deal data space and its accompanying Destination Earth digital twin of the earth.

The ELISE Action, part of the ISA^2 programme, is addressing the challenges and opportunities in location interoperability, in terms of studies, frameworks, application pilots and re-usable tools. The ELISE work programme initiated in 2016, entered into the final execution phase with a substantial programme of studies to identify key aspects of digital transformation of government and to understand the impact of digital technologies (i.e. digital platforms, APIs, blockchain and distributed ledger, AI, etc.) on the delivery of innovative public services leading to a digital transformation of governments, design and roll-out of pilots in various thematic areas (i.e. energy, transport, public administration, etc.).

Within this context, location interoperability is defined as the ability of organisations, systems and devices to exchange and make use of location data with a coherent and consistent approach. The ELISE work programme has a particular focus on developing and piloting approaches to apply location intelligence to the delivery of public services in smart cities. The smart cities concept includes deploying urban platforms, digital twins of cities and other digital ecosystems leveraging geospatial information. However, smart cities are part of a wider trend - the Smart Space, a combination of physical and digital environments in which people and technology-enabled systems interact in dynamic, inter-connected and intelligent ecosystems.

The aim of this report is to address the role of the *public sector in relation to location intelligence in Smart Spaces* – by developing a benchmarking framework , as well as by providing recommendations on how to improve the use of location intelligence in smart spaces by benchmarking four representative case studies.

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This study would not have been possible without the contribution of stakeholders interviewed during the case study analysis process. Namely, we would like to thank Timo Ruohomäki from Forum Virium, R.J.M.M. van der Heijden from Digital City Rotterdam, Ricardo Vitorino from Ubiwhere, Andraž Logar, from 3fs and all their colleagues who provided their support. We are also gratefull for the support of several colleagues of the European Commission who helped in the early scoping of the benchmarking framework, the case study selection, and the review of earlier versions of this document.

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Executive Summary

The wide diffusion of technologies, such as cloud computing, the Internet of Things (IoT), and 4G/5G, has enabled many cities to transform into hubs of digital transformation, deploying urban platforms, digital twins of cities and other digital ecosystems that leverage geospatial information. Smart cities are part of a wider trend, which has a strong element of location - the *Smart Space*, which also includes smart buildings and much more. A Smart Space can be defined[1] as a combination of physical and digital environments in which people and technology-enabled systems interact in dynamic, inter-connected and intelligent ecosystems. Such Smart Spaces represent a new approach in terms of design and integration patterns and architectures to create new outcomes from legacy, new and emerging technologies and services.

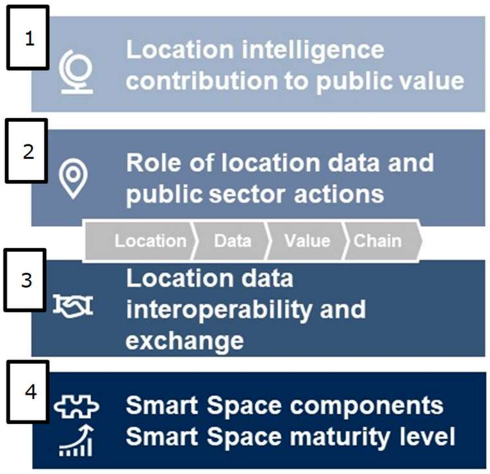
While we witness the market for Smart Spaces expanding, we lack a deeper understanding of its challenges and the possible solutions that location intelligence might provide. We see a particular opportunity to identify areas where the public sector can help address these challenges. It will thus inform relevant policies, such as the interoperability policy and the EU Data Strategy.

Developing a benchmarking framework to analyse Smart Spaces in this context is particularly important to identify barriers, for example, in the interoperability of (location) data and technology, anticipating emerging market demands, and the derived recommendations for improving the status quo – especially for required actions of the public sector.

This report[2] details how the ***Smart Space Benchmark Framework*** was designed, highlights the insight gathered from the four case studies, presents an analysis of how to improve the use of location intelligence in Smart Spaces, and provides conclusions and recommendations. Our conclusions reflect and distil the outcomes of these areas of study, setting the key takeaways from benchmarking the roles of the public sector and location intelligence in a wider context and suggesting future research. Since this study is developed in the scope of the *"European Location Interoperability Solutions for e-Government (ELISE)*", Action 4.1 of the ISA2 Programme, we close with recommendations for the public and the private sectors with regards to location data and interoperability.

The *Framework* can be used to benchmark Smart Spaces along **four dimensions** (see also Figure 1), structuring the collection of data to provide insight on the role of location intelligence in Smart Spaces and the role of the public sector. The first dimension allows understanding how, in a Smart Space, data is used to create public value using location intelligence. The second and third dimensions help to analyse in detail location data and intelligence and how it is exchanged, along the data value chain, the existing barriers and enablers, and the role of the public sector. The fourth dimension addresses the overall Smart Space by looking at its components and assessing its maturity level.

Figure 1. The four dimensions of the Smart Space Framework



[1] Gartner (2019a), Gartner Identifies the Top 10 Strategic Technology Trends for 2020, Press Release, October 21, 2019, https://www.gartner.com/en/newsroom/press-releases/2019-10-21-gartner-identifies-the-top-10-strategic-technology-trends-for-2020

[2] This report and related materials are available in the ELISE collection activity page "Smart Space Benchmark overview" on Joinup: https://joinup.ec.europa.eu/node/704569

To extract the relevant information from the distinct case studies, we developed a template representing the four dimensions of the analytical Framework. This template was applied to four carefully selected case studies throughout this work.

- The first case study is an application of the Urban Open Platform work package of the FinEst Twins project (in Estonia and Finland). The project's goal is to pilot generic real-time data processing capabilities and provide a proof-of-concept implementation of cross-border geospatial models and specific solutions in the domain of Smart Mobility.
- The second case study is led by the Municipality of Rotterdam (the Netherlands), investigating the possibilities for the future city in the Digital City program. The core of this program is the development of a digital Open Urban Platform with a 3D Digital Twin of Rotterdam, in which all fixed physical objects (houses, trees, benches, etc.) in the city are included.
- The third case study is the Urban Platform offered by Guimarães (Portugal) - a city dashboard that presents information, updated in real-time, from different domains and several sources such as sensors, platforms, services, and even the citizens themselves. It supports features for operational activities, such as faster response to road accidents, traffic flow improvement, etc.
- The fourth case study stems from the call to action by the City council of Kranj (Slovenia) for companies to develop pilots for innovative smart city solutions. The Smart Mlaka pilot is a cooperation between regional IoT companies, resulting in a "public cloud first" smart city solution, developed in a lean and agile way in collaboration with the city council.

Insights gathered from the case studies using the template highlighted the role of location intelligence in Smart Spaces. We analysed the use of location intelligence in a Smart Space following the various roles of location data that we identified, namely (i) location data is the service, (ii) location data adds intelligence, and (iii) location data supports data validation activities. The case studies also revealed the type of location intelligence generated in the Smart Space, its impact, and public value. Finally, experiences from the case studies also helped identify the various roles of actors from the public sector in a Smart Space.

We identified the **barriers and enablers** to the market uptake in the four case studies and analysed related public sector actions. This allowed us to derive a set of **five areas where the public sector can act** to lower the barriers of implementing Smart Spaces: (1) funding and financing (2) trusting and valuing the investment (3) stimulating availability of (location) data, (4) ensuring interoperability, and (5) facilitating uptake.

In our conclusions, we extract the key takeaways from benchmarking the roles of the public sector and location intelligence in a wider context and suggest **future research**, including:

(a) Benchmarking the roles of the public sector. From the four cases that we examined, public sector roles as data provider and data consumer seem common across the value chain. However, the role of data broker appeared limited to providing access to the data at the exchange step. Other existing examples contradict this restricted view[3]. We thus need to apply the developed framework to a larger set of case studies to validate and enrich our initial findings.

(b) Benchmarking location intelligence and its contribution to public value. From the cases that we selected for this work, we can conclude that the public value gained through applying location intelligence in Smart Spaces is overall perceived as medium to high - with a predicted increase over time. Given that these assessments were a first generic attempt, we see a need to dive into more details and embrace results from other ongoing works. Also, the evolution of Smart Spaces and their data ecosystems should be considered in future activities.

(c) Development and future usage of the benchmarking framework. Whereas the benefits of a detailed and comprehensive framework reside in knowledge gathering and sharing, we would also see value in deriving a lighter version of the Framework, which could provide a "fast benchmark tool" in focused areas, such as interoperability landscapes or the roles of the public sector. With a targeted focus, such a "self-assessment" benchmark framework could be deployed over a larger number of cases and provide a more representative view of the Smart Space landscape in these areas. It might also contribute to monitoring the ongoing digital transformation in the public sector.

[3] See example of the pipeline and cable information exchange portal (KLIP), in Gartner (2020a), ELISE Report: Location intelligence benchmarking study, https://joinup.ec.europa.eu/collection/elise-european-location-interoperability-solutions-e-government/document/report-location-intelligence-benchmarking-study

Finally, as this study is developed in the scope of the ELISE action, we then close this report with further **recommendations** for the public and the private sectors regarding location data and interoperability. Table 1 summarizes those recommendations vis-à-vis the previously identified barriers.

Table 1. From barriers to recommendations for the public and the private sector

<table>
<tr><th>Barrier</th><th>Public sector actions, incl. policy</th><th>Private sector actions</th></tr>
<tr><td rowspan="2">Lack of data, incl. its discoverability and access</td><td>Champion data sharing policies: including the INSPIRE Directive, Open Data Directive, European Strategy for Data, the (upcoming) Data Governance Act, the (proposed) Data Act, etc.
Drive location intelligence initiatives
Procure data sets, clarify ownership of data
Procure common data capturing devices for multiple systems</td><td>Contribute to develop a Common European Data Space, and applications building on top of it
Promote a culture of data sharing</td></tr>
<tr><td colspan="2">Develop Public-Private Partnerships: Common data platforms and marketplaces such as Copernicus with Data and Information Access Services (DIAS[4])
Promote common initiatives between cities (Living in EU[5])
Consider the billions of IoT devices as a shared infrastructure and ensure the monitoring of their quality and maintenance under common programmes</td></tr>
<tr><td rowspan="2">Lack of interoperability</td><td>Champion interoperability-related policies: EU Standardisation rolling plan[6], European Interoperability Framework, Location Interoperability Framework, (upcoming) Interoperability Policy
Benefit from DIGITAL (incl. Interoperable Europe) for the reuse of existing solutions, including open-source ones[7]
Encourage/ enforce usage of open standards, including usage of Open APIs for integration</td><td>Innovate integration mechanisms, technology and tools</td></tr>
<tr><td colspan="2">Participate in common standardisation activities</td></tr>
</table>

The recently launched Digital Europe Programme (DIGITAL), especially including its Interoperable Europe initiative, provides plenty of opportunities to take the required actions, share the experiences, and adopt new interoperable solutions for the benefit of all.

[4] Copernicus Data and Information Access Services (DIAS), https://www.copernicus.eu/en/access-data/dias
[5] Web presence of the LivingIn.EU initiative, https://living-in.eu/
[6] EU Rolling Plan for ICT Standardisation, https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/rolling-plan-2020
[7] EU Open Source Observatory (OSOR), https://joinup.ec.europa.eu/collection/open-source-observatory-osor/news/study-open-source-policies

1 Introduction

In recent years, the wide diffusion of technologies (such as cloud computing, Internet of Things (IoT), and 4G/5G) has enabled many cities to transform into hubs of digital transformation deploying urban platforms, digital twins of cities and other digital ecosystems leveraging geospatial information. These trends are raising the challenge of digital transformation in the European Union (EU), requiring an adaptation of its organisational structures, service models, policy frameworks and governance systems.

The *Digital Economy Unit* of the European Commission's Joint Research Centre (JRC) initiated research in the area of Digital Transformation and Artificial Intelligence in 2018, including efforts to address the impact of digital transformation on government. Here, the Digital Economy Unit cooperates with other services of the European Commission, especially with the European Commission's department for informatics (DIGIT), and it coordinates the "European Location Interoperability Solutions for e-Government" (ELISE) Action of the ISA² Programme.

The **ELISE Action** provides a package of legal, policy, organisational, semantic and technical interoperability solutions to facilitate efficient and effective electronic cross-border or cross-sector interaction between European public administrations and between them and citizens and businesses. It particularly focuses on location information and services supporting the European Digital Single Market, Better Regulation and Public Sector Modernisation.

Within this context, the work presented in this document addresses the role of the **public sector concerning location intelligence in Smart Spaces** – following a benchmarking approach. This work was carried out as part of the specific contract n° 473 based on framework ABC IV Contract — Lot 2, "ISA² – Action 10: ELISE Benchmarking Support 2020-2021".

1.1 Central concepts

The ELISE work programme has recently focused on developing and piloting approaches to apply location intelligence to delivering public services. **Location intelligence** is defined[8] as the *process of deriving meaningful insight from geospatial data relationships – people, places or things*. Within the context of this work, **location interoperability** is defined[9] as the *ability of organisations, systems and devices to exchange and make use of location data with a coherent and consistent approach*.

Smart cities are part of a wider trend, which has a strong element of location - the **Smart Space**, which also includes smart buildings, smart cities, and many more.

A **Smart Space** can be defined[10] as *a combination of physical and digital environments in which people and technology-enabled systems interact in dynamic, inter-connected and intelligent ecosystems*. Such Smart Spaces represent a new approach in terms of design and integration patterns and architectures to create new outcomes from legacy, new and emerging technologies and services.

Early Smart Spaces emerged as "islands of innovation" – for example, in municipalities. These early solutions were typically narrowcasted point solutions related to lighting, building infrastructure, or energy demand management. Opportunities are increasing to drive more connected, coordinated and intelligent solutions. This is the result of trends related to artificial intelligence (AI), the expansion of IoT-connected edge devices, and digital twins' development.

Gartner[11] sees market demand accelerating for Smart Spaces as emerging technologies and techniques, such as IoT and artificial intelligence (AI), are increasingly available at a greater scale. Ecosystems that emerge in these Smart Spaces will enable multiple entities — government, IT providers, enterprises and even consumers — to interact with one another to deliver a dynamically integrated system. While Smart Spaces will evolve in these islands of innovation, the full vision will probably take 10 or more years to mature.

[8] Gartner (2020a), see also footnote 3.

[9] European Union Location Framework (EULF) Blueprint available in version 4.0 in Boguslawski R., Valayer C., van Gansen K., Keogh D., Pignatelli F. (2020), European Union Location Framework Blueprint, EUR 30374 EN, Publications Office of the European Union, Luxembourg, doi:10.2760/096595, JRC117551, and online at http://data.europa.eu/w21/8e942bc2-657a-4289-b057-f2a285ee7375

[10] Gartner (2019a), see also footnote 1.

[11] Gartner (2020b), VC Investment Growth Insights for Smart Spaces, ID: G00463988

In the context of the European data strategy, a **data space** refers to *a pool of data, associated tools and infrastructure necessary to use and exchange data, as well as appropriate governance mechanisms serving data needs in a particular policy area (e.g. health, mobility, environment, smart communities) and having a systemic impact on the entire ecosystem*[12]. *Access and reuse of public (and publicly funded) and private data constitutes major cornerstones of a* ***common European data space***[13]. A **community data space** provides access to data that can generate user value, and it provides the tools, infrastructure etc., to generate data ecosystems (3D maps, sensors, etc.).

The infrastructures should support the creation of European data pools enabling Big Data analytics and machine learning in a manner compliant with data protection legislation and competition law, allowing the emergence of data-driven ecosystems. Data spaces should foster an ecosystem creating new products and services based on more accessible data.

A **data ecosystem** is defined[14] as a setup where *a number of actors interact with each other and their environment for a specific purpose, generating value from the network by producing, exchanging and consuming data in a collectively governed and operated way.* Data ecosystems will stem from and generate value in the data spaces.

Smart Spaces use data spaces by adding dedicated applications and intelligence on top of them. Smart Spaces can also contribute to data to data spaces. Overall, they are part of the data ecosystem.

1.2 Scope and structure

While we witness the market for Smart Spaces expanding, we lack a deeper understanding of its challenges and the possible solutions that location intelligence might provide to the needs of the private sector. Within the context of ELISE Action, we see a particular opportunity to **identify the public sector's current position and derive actions for overcoming major challenges**. It will thus inform relevant policies, such as the interoperability policy and the EU Data Strategy.

Developing a **benchmarking framework** to analyse Smart Spaces in this context is particularly important to identify barriers, for example, in the **interoperability** of (location) data and technology, anticipating emerging market demands, and the derived recommendations for improving the status quo – especially for required actions of the public sector. Notably, any such Framework would have to be applicable at the generic level of Smart Spaces, i.e. to a large degree, independent of the nature of the Smart Space (smart city, smart village, smart building, etc.).

The focus of the work presented here is on **analysing the role of the public sector in relation to location intelligence, the application of AI, and the use of location data and technology, within these Smart Spaces**. The Smart Space Benchmark Framework developed in this study provides a means to analyse and compare Smart Spaces across several dimensions, particularly the role of both location intelligence and the public sector. It should also help to reveal how data is used to create public value using location intelligence.

This report presents how the Smart Space Benchmark Framework was designed (Section 2), highlights the insight gathered from the four case studies (Section 3), discusses how to improve the use of location intelligence in Smart Spaces (Section 4), and presents conclusions and recommendations (Section 5). Additional details about the four case studies are provided in the annex. The report itself, and additional materials, such as the recording of the closing Webinar, are available on the ELISE Action collection activity page[15].

[12] A European strategy for data, https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1593073685620&uri=CELEX%3A52020DC0066

[13] Towards a common European data space, https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52018DC0232

[14] European Union Location Framework (EULF) Blueprint, see also footnote 9.

[15] Smart Space Benchmark overview page on Joinup, see also footnote 2.

2 Designing the Smart Space Benchmark Framework

This section details the approach of creating the Benchmarking Framework by analysing location intelligence and the role of the public sector in Smart Spaces.

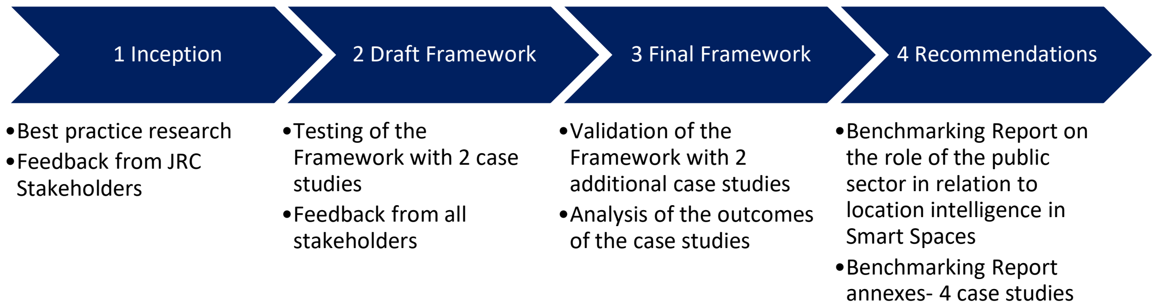
2.1 Sketching the methodology

The Framework was developed incrementally, taking into account best practices in the field of location data and the role of the public sector, and two stages of feedback (see also Figure 2)[16].

1. At the inception phase, a first set of dimensions were proposed, and the study team identified relevant related work that provides best practices for the scope of this Framework.
2. The second phase aimed to test the framework's first draft with various stakeholders and carried out a "dry-run" with two case studies.
3. In a third phase, after taking into account the feedback from the previous step, two other case studies were examined using the full benchmarking framework. This allowed validating and fine-tuning the dimensions. This was our way to ensure that the outcome of the investigations using the Framework delivers on the purpose of the study, i.e. to identify the role of the public sector concerning location intelligence in Smart Spaces and highlight major challenges together with enablers to overcome them.
4. In the fourth phase, we derived recommendations on overcoming challenges based on the case study analysis.

This report focussed on the outcomes of stages three and four. More specifically, it details the content of the case studies focusing on the aspects relating to the public value, public sector roles in a Smart Space and public sector actions relating to barriers and enablers. The more technical content of the case studies is included in the annexes to this report.

Figure 2. Phases for developing this report



2.2 Specifying the aim of the framework

The Framework aims to structure the collection of data to provide insight into the role of the Public Sector concerning *Location Intelligence* in Smart Spaces. From the discussions during the inception phase of this project, a set of six focus areas emerged targeting the aimed insight, namely (1) the role and added value of location data in Smart Spaces, (2) the role of the public sector concerning location intelligence in Smart Spaces, (3) challenges hindering market uptake, (4) the role of the public sector concerning enablers of usage of Smart Spaces, (5) the capabilities supporting data exchange, and (6) the components of Smart Spaces. The focus areas and related research questions are detailed in Table 2 below.

Notably, the Framework should, in principle, cater to different types of Smart Spaces, i.e. a Smart City and a Smart Building, providing an analysis approach applicable to different levels of granularity.

[16] Three workshops were organised to collect feedback from the JRC stakeholders. For the other stakeholders (the European Commission's Directorate-General for Communications Networks, Content and Technology (DG CONNECT) and case study participants "dry-running" the Framework), an additional workshop and interviews were set up to test the proposed dimensions of the draft Framework and the inherent values for each dimension.

Table 2. Research questions for the Smart Space Benchmark Framework

Focus areas	Research questions
Role and added value of location data in Smart Spaces	What is the role of location data versus other data? Does it help to add intelligence, and how? (e.g., Does location data enable descriptive, predictive, or prescriptive analytics?) How does location intelligence relate to public value?
Role of the public sector concerning location intelligence in Smart Spaces	What is the role of the public sector regarding location intelligence? For example, is location data used to deliver public service in the Smart Space? Does the public sector have an operational and/or strategic role (e.g. consumer of location data, data provider, data broker, actor in data governance, creator of standards, etc.)?
Challenges hindering market uptake	What are the challenges hindering the market uptake of Smart Spaces - and more specifically, those relating to location intelligence? Are the challenges strategic and operational (e.g., lack of interoperability, lack of data governance mechanisms, lack of cohesion in architectures, lack of cohesive ecosystem, lack of skills, security risks, legacy integration, lack of resources, lack of infrastructure)?
Role of the public sector concerning enablers of usage of Smart Spaces	How can the public sector provide support in overcoming these challenges? What enablers relating to the use of data (and more specifically location data) within a Smart Space can the public sector contribute to, and how?
Capabilities supporting data exchange	How is location data exchange supported inside the Smart Space? (Are Application Programming Interfaces (APIs) used and where? Is a Context Broker used? Which standards and protocols are used?) How is location data exchanged across different Smart Spaces?
Components of Smart Spaces	What are the typical components of a Smart Space? Do Smart Spaces include digital twins? What type of infrastructure is used (e.g. Digital Twin, Urban Platform)? Which methods and tools/devices are used to capture data? What data ecosystems are involved, and which networks of actors do already exist?

2.3 Detailing the four dimensions of the framework

In order to answer the research questions identified in Table 3, the research analysis developed the following four dimensions of the framework. The table below describes for each focus area the Framework dimension it relates to and the analysis descriptions that are used to structure the research.

The logic behind the layering in four dimensions is to highlight the value creation from location intelligence in a Smart Space. The dimensions are deliberately presented in the following order (see also Figure 3):

- The top of the framework (Dimension 1) addresses the added value of location intelligence in its usage, and it will be addressed by analysing dedicated use cases (i.e., What does the usage of location intelligence in the Smart Space allow people to do?).
- On both sides of the data value chain, Dimension 2 and Dimension 3 analyse location data and location intelligence in detail; these analyses reveal how data is exchanged, the barriers and enablers, and the role of the public sector.
- At the bottom of the framework (Dimension 4), the overall Smart Space is analysed by looking at its components and assessing its maturity level.

Table 3. Dimensions of the Smart Space Benchmark Framework

Focus area	Framework dimension	Required analysis
Role and added value of location data in Smart Spaces	*Dimension 1: Location Intelligence contribution to Public Value in Smart Spaces*	Analysis of the role of location data (i.e., how does it provide intelligence) in Smart Spaces and its contribution to public/business value[17].
Role of the public sector concerning location intelligence in Smart Spaces	*Dimension 2: Role of Location Data and Public Sector actions*	Analysis of the role of location data in the data value chain[18], the role of the public sector with respect to location data and location intelligence, the challenges and enablers of the Smart Spaces, and the actions that the public sector can undertake to lower the barriers of using location intelligence in a Smart Space.
Challenges hindering market uptake		
Role of the public sector concerning enablers of usage of Smart Spaces		
Capabilities supporting data exchange	*Dimension 3: Location Data interoperability and exchange*	In each step of the data value chain, description and analysis of how location data is exchanged in the Smart Space, including the technologies and interoperability initiatives involved.
Components of Smart Spaces	*Dimension 4: Smart Space Components and Maturity*	Identification of the components of the Smart Space, and the maturity level of the Smart Space overall.

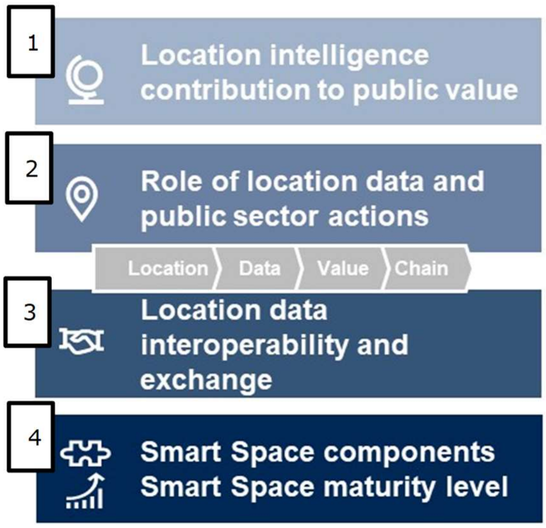
The Framework dimensions are developed considering the Framework's usability, especially its ease of use in terms of the length and the number of questions to reply to. The aim is to develop a useful tool that can provide a clear impression of a Smart Space, including location data and intelligence and the role of the public sector in the Smart Space. In this way, it should enable benchmarking along the dimensions and – ultimately – serve as a practical guidance on how to develop a Smart Space, how to leverage location intelligence, and where to focus related policy and investments

This Framework applies to different levels of analysis (e.g. a Smart City or a Smart Building). There are no differences in the questions whether addressing a Smart City or a Smart Building. For example, the structure of the enablers and barriers is applicable to any Smart Space. Other dimensions focus on analysing the use cases of the Smart Space, which are selected during the analysis.

[17] In contrast to Dimension 2, this dimension investigates the notion of "public value" in public services, and how location data contributes to it through its usage in public services.

[18] In contrast to Dimension 1, this dimension investigates another aspect of value: the data value chain, which is a concept analysing the information flow as a series of steps generating value and usefulness of the data itself.

Figure 3. The four dimensions of the Smart Space framework



2.4 Defining the case study template

To extract the relevant information from the different case studies, we developed a template representing the dimensions and focus areas of the Framework. Several versions of the template were used throughout this work in the case studies - each new one being a refinement of the previous, including stakeholder feedback. This section presents the latest version of the case study template for analysing location intelligence and the role of the public sector in Smart Spaces. The template results from in-depth testing and practical application throughout this work and is one of its re-usable outcomes.

The templates first capture a set of items that explains the case study and covers some basic information, such as a means of contact and the category of the lead organisation (governmental organisation, non-governmental organisation, private-sector organisation, etc.), see also Table 4.

Table 4. Smart Space Benchmarking Framework template, section for basic information

Smart Space Benchmark Framework: A case study template for analysing location intelligence and the role of the public sector in Smart Spaces.			
Case Study Description			
Name	URL		Contact
Lead Organisation Name		Lead Organisation Category	
Description			
Administrative level	Geographic coverage	Start Date	Still Active

Dimension 1 relates to the added value of location intelligence in its usage by analysing use cases (i.e., what the usage of the Smart Space allows people to do) and, more specifically, what type of location intelligence is used. Here, we distinguish between:

- descriptive analytics that uses data to describe, summarise and visualise information, as well as mining and aggregating current and historical data to gain insight;
- predictive analytics that uses machine learning with data to make predictions and uses statistical and probabilistic techniques to predict future trends and outcomes; and
- prescriptive analytics that recommends courses of action to achieve an outcome by making decisions.

This section of the template (see Table 5) also provides insight into how location intelligence has an impact on the type of decision making, which can be either "Strategic" – i.e. it refers to a strategic decision such as where to place a building, or "End-user" – i.e., it refers to the functionality provided to the end-user such as route recommendations.

Here, we also identify if this impact is:

- long-term, i.e. the decision has a high economic and/or timely impact, with the decisions, for example, implying a significant investment, and/or is expected to last from a few months to years (for example, constructing a new building);
- mid-term, i.e. the decision has a high economic and/or timely impact, with the decisions, for example, implying a moderate investment, and/or is expected to last from days to months (for example, adjusting distribution routes); or
- short-term, i.e. the decision has a small economic and/or timely impact, the decision is made immediately, has a low individual cost and is expected to last from minutes to days (for example, optimisation of waste disposal).

The analysis of the use cases also identifies how they contribute to public value. The value assessments (low, medium and high) are made relative to each use case. This implies that they are not necessarily comparable across use cases, but within these limitations, the Framework provides a good view of which public value is identified as most served in the Smart Space.

Table 5. Smart Space Benchmarking Framework template, section for Dimension 1

Dimension 1: Location intelligence contribution to the public value in Smart Spaces			
Please select several use cases of the Smart Space. For each use case, select the type of location intelligence the use case provides and the type of decision making and impact that location intelligence in the use case has. For each use case, select the value level for each of the four values.			
Example Use Case	**Location intelligence type**	**Type of decision making and impact**	
Please provide use case name and short description Enter text here	*Please select one or several items from the list below* (1) descriptive analytics (2) predictive analytics (3) prescriptive analytics	*Please select one or several items from the list below* - End-user - Strategic	*Please select one or several items from the list below* - Short term - Medium-term - Long term
Public Value of the use case			
Please select for each value: none, low, medium or high			
Economic and financial value (incl. efficiency)	**Citizen value and user attractiveness** (incl. social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. transparency)
- None - Low - Medium - High	- None - Low - Medium - High	- None - Low - Medium - High	- None - Low - Medium - High

Dimension 2 analyses the role of location data and the role of the public sector in the Smart Space, using the data value chain[19], which is used to deepen the insight collected by detailing the analysis for each step:

[19] We consider a data value chain as a framework to assess the activities that develop data into assets which companies can exploit to generate value as part of their commercial activities. This value is generated by collecting and monetising data. Source: GSM Association

generation, collection, processing and exchange (see Table 6 for the template). To qualify the role of location data and how it contributes to the data value chain, we leverage a framework developed by Gartner in the Digital Platform Study for JRC,[20] where we analysed the different roles of location data. The barriers and challenges are then analysed further to identify the areas where the public sector actions drive better uptake. To classify enablers and barriers, we created a list including elements from general previous research experiences and on Gartner research[21] relating to challenges for the adoption of integrated Smart Space solutions, which we refined during the first case study analyses.

Table 6. Smart Space Benchmarking Framework template, section for Dimension 2

Dimension 2: Role of Location Data and Public Sector actions
Please read the description below of the Data Value Chain Steps. Select a use case of the Smart Space from the ones described in Dimension 1. Complete the table on the role of location data: mark with an X in which step of the value chain the different roles of location data is seen and explain with an example for each of the steps. Complete the table on the role of the public sector in a similar way. **Selected use case name:** *put the name here*

Data Value Chain Steps			
Generation	**Collection**	**Processing**	**Exchange**
Data acquisition Information is captured in a digital format from devices.	Data organisation: collection and validation Collection and consolidation of data from multiple sources. Comprises checking of the data accuracy before integration into a valid dataset.	Data processing and analysis Processing data to generate insight by identifying patterns in the data, including descriptive, predictive and prescriptive analytics.	Data sharing and publishing Data is shared and published (through APIs, data portals, for example) to be used. At this stage, it can also be reused or repurposed.

	Data value chain			
Role of location data	Generation	Collection	Processing	Exchange
Location Data is the service: Location data or location intelligence algorithms are the main value-generating component of a service. (Example: Navigation service) *Please provide explanations for each "X" selected: Does the use case generate location data to then deliver it as a service? Does the use case collect location data to then deliver it as a service? Etc.*	X	X	X	X
Location Data adds intelligence Location data or location intelligence algorithms enrich the value generated by products or services. (Example: Shortest route calculation)	X	X	X	X

(2018), The Data Value Chain, https://www.gsma.com/publicpolicy/wp-content/uploads/2018/06/GSMA_Data_Value__Chain_June_2018.pdf

[20] Valayer, C. Van Gansen and K. Allessie, D. (2018), Digital Platforms for Public Services - Final Report, p.15, https://joinup.ec.europa.eu/node/ 701469

[21] Gartner (2020c), Emerging Technology Analysis: Smart Spaces, ID: G00726960

Please provide explanations for each "X" selected: Does the use case use location data to add intelligence at the generation/ collection/processing/exchange phase?				
Location Data supports data validation activities: Location data is used to validate other data sets. (Example: Location data in lampposts validate earthquake information identified by other sensors) *Please provide explanations for each "X" selected: Does the use case use location data to validate other data sets at the generation/collection/processing/exchange phase?*	X	X	X	X
	Data value chain			
Role of the public sector	Generation	Collection	Processing	Exchange
Data provider *Please provide explanations for each "X" selected: Is the public sector a data provider at the generation / collection / processing / exchange phase?*	X	X	X	X
Data consumer *Please provide explanations for each "X" selected: Is the public sector a data consumer at the generation / collection / processing / exchange phase?*	X	X	X	X
Data broker *Please provide explanations for each "X" selected: Is the public sector a data broker at the generation / collection / processing / exchange phase?*	X	X	X	X
Data Owner *Please provide explanations for each "X" selected: Is the public sector a data owner at the generation / collection / processing / exchange phase?*	X	X	X	X
Supports or enforces standardisation *Please provide explanations for each "X" selected: Does the public sector support standardisation or enforce (i.e., in procurement) the use of standards in the generation/collection/processing/exchange phase?*	X	X	X	X

Enablers and barriers of a Smart Space and location intelligence, and related public-sector actions

Please fill in the table on enablers and barriers of a Smart Space, select with an "X" the barriers which apply in your case, and add additional ones where applicable. Please add or delete the related Enablers and proposed Public sector Actions.

Barriers		**Yes** *Please select*	**Enablers** *Please add and/or delete*	**Public sector action** *Please add and/or delete*
Economic	Lack of funding, uncertainty relating to hidden costs	*X*	Financing/ Funding	Funding means (Public-private partnerships)

Enablers and barriers of a Smart Space and location intelligence, and related public-sector actions			
	Low demand: Lack of trust in the use cases and technology value not perceived	Cost/benefit Analysis	Innovation value identified (Public-private partnerships, communicating on user stories, etc.)
Organisational	Lack of political drive	Visibility	Raise awareness, showcase value proposition
	Need for orchestration and maintenance of new and legacy technology across many manufacturers	Openness	Open standard compliance as a requirement in all tenders
	Lack of data Difficulty in accessing data	Data spaces, data market places and communities	Procurement of new data sets Data owner is the public sector Promote data marketplaces Engage citizen community with data sharing
Legal	Data Privacy issues	Regulations	Compliance with GDPR and other regulations
Technical	Lack of computation capacity	Partnerships Data spaces	Collaboration models Procurement for IT computation
	Lack of innovative technology (ex: real-time data sharing)	Partnerships	Innovation collaboration models
	Lack of trust in investing in technology (ex: Cloud)	Partnerships	Innovation collaboration and risk-sharing models Training and Skills Acquisition
	Interoperability[22]	Standards	Open standard compliance in procurement
	Lack of skills	Training Partnerships	Public-private partnerships Training and Skills Acquisition
	Lack of trust in security		Partnerships and Skills Acquisition

Dimension 3 analyses the location data exchange capabilities (see Table 7 for the template). For this, we leverage a Gartner framework[23], mapping existing data integration approaches along with data-centric, event-centric and application-centric styles. Data-centric integration assumes that integration is about moving data from one place to another and converting from one data model to another. It is most commonly associated with batch extract, transform and load (ETL) tools but can deliver data in near real-time. Event-centric integration focuses on delivering events, or streams of events, to the endpoints where they are consumed. Application-centric integration involves invoking and composing functionality rather than accessing data (although that feature may be to retrieve some data). Dimension 3 also analyses the interoperability landscape by mapping the standards used. This section of the Framework is aimed at a technical audience.

[22] For new systems, as well as for usage of older IT, assets that lack integration and data acquisition standards.
[23] Gartner (2019b), Choosing Between Data-, Application- and Event-Centric Integration Styles, in Gartner: A Spectrum of Data Integration Approaches, ID G00377052

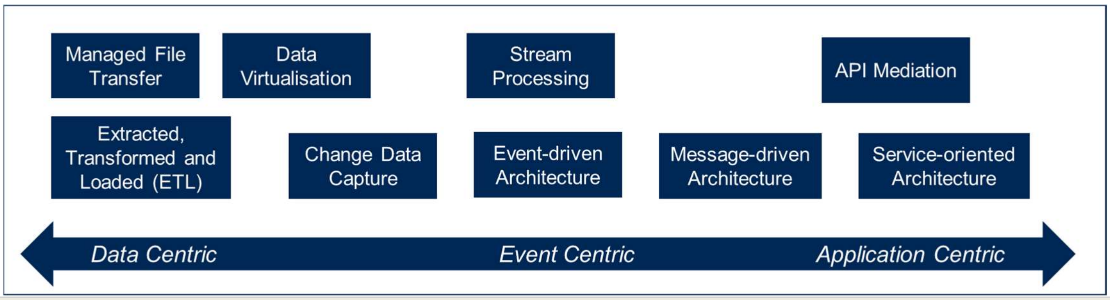
Table 7. Smart Space Benchmarking Framework template, section for Dimension 3

Dimension 3: Location data interoperability and exchange
Use case: *put the name here*

From the different data integration styles depicted in the figure below, please identify those used in the use case. For each integration style used (in columns of the table), please

1. *Describe the location data set type and standard used; and*
2. *List the tools used (solutions, software) for exchanging these data sets.*

Figure 4. Overview of data integration styles



Location data exchange capabilities

Integration styles	Managed file transfer	ETL (Extraction, Transformatio	Data virtualisation	Change data capture	Stream Processing	Event-driven architecture	Message-Driven Architecture	API mediation	Service-oriented architecture
(1) Location data set type and standards									
(2) Tools									

Please describe, for each step of the value chain

1. *the location data sources*
2. *the tools used*
3. *the standards used (for each area) and indicate where you estimate standards are missing*

Location Data – Tools and Standards

	Data Value Chain			
	Generation	Collection	Processing	Exchange
(1) Location Data Sources				
(2) Tools				

	Data Value Chain			
	Generation	Collection	Processing	Exchange
(3) Standards				
Artificial Intelligence				

Smart City and Digital Twin				
Internet of Things				
Event Stream Processing				
Building Information Modelling				
Open Data Standards				

Dimension 4 analyses the maturity of the Smart Space and the different elements composing it. The corresponding section of the template is provided in Table 8. Gartner research[24] specifies a Smart Space maturity model, with four phases of Smart Spaces underscored by five dimensions. We selected it due to its genericity and applicability in many types of Smart Spaces, compared to other models investigated during the inception phase. We also proposed a list of updated and completed components during the case study analyses, providing a comprehensive view of the Smart Space elements.

Table 8. Smart Space Benchmarking Framework template, section for Dimension 4

Dimension 4: Smart Space maturity and components				
Please read the Smart Space Maturity model presented below and please select the level corresponding to your Smart Space by highlighting in bold the blue font.				
Smart Space Maturity Level				
Stage	**Phase 1 Isolated Systems**	**Phase 2 Connected Systems**	**Phase 3 Coordinated Systems**	**Phase 4 Intelligent Environments**
Openness	none	Internal	External	Fully
Openness. Openness refers to the degree of accessibility to the elements in a Smart Space, including data. In an open model, systems can interact with each other with data exposed and accessible through standardised mechanisms. Trends in open data formats, identifiers and protocols, as well as the work of open-source communities, are driving this aspect of Smart Spaces.				
Connectedness	none	Yes	Yes	Yes
Connectedness refers to the depth, breadth and robustness of the connections between the elements in a Smart Space. Connectedness is closely linked to openness. As the mechanisms to access the attributes, data and functions of an application increase, so does the degree of openness. Increasing the granularity of the accessible attributes, data and functions also increase connectedness. Trends such as IoT, IoT platforms, digital twins, edge computing, APIs and API gateways, and mesh app and service architectures all contribute to greater connectedness in a Smart Space.				
Coordination	none	Integration	Coordination	Coordination
Coordination refers to the depth and strength of coordination between the elements in a Smart Space. Coordination is a more active aspect of Smart Spaces that build on connectedness. While connectedness looks at the opportunity to connect various elements, coordination looks at the actual level of interaction and cooperation between the elements. For example, two applications operating in a Smart Space that shared login				

[24] Gartner (2019c), Top 10 Strategic Technology Trends for 2019: Smart Spaces, ID: G00377685

credentials would have a very low coordination score. However, if they shared data and had tightly integrated process execution, they would have a much higher coordination score. Trends such as MASA, APIs and events also factor into coordination. Coordination in this context refers not only to technical coordination but also to the coordination of people and processes based on the underlying technology.				
Intelligence	none	none	Semi-intelligent	Intelligent
Intelligence refers to the use of machine learning and other AI techniques to drive automation into the Smart Space and deliver services to augment the activities of people within it. Intelligence can manifest itself in the form of autonomous things or augmented intelligence, including augmented analytics. An important aspect is the use of AI to deliver intelligent multimodal and multidevice immersive experiences to enhance how users perceive and interact with the various elements in the Smart Space.				
Scope	Team	Department	One organisation	Ecosystem
Scope refers to the breadth of a Smart Space and its participants. A Smart Space with a very narrow scope might focus on a single team within a department of a large organization. A Smart Space with a broader scope might focus more across the organization but within a bounded problem space. A Smart Space with an even broader scope might include elements external to the organization with an ecosystem of participants. Openness, connectedness and coordination set the stage for increasing the scope of a Smart Space. Intelligence promotes simplified access and automated management as the scope of a Smart Space increases.				

Please describe the Components of the Smart Space in a few lines for each category. Example: What are the different data sources? What technology is used to capture location data? What type of cloud is used and for what purpose? What solution provides the analytics? How are integration and interoperability addressed? What ecosystem is the Smart Space part of?

Smart Space Component Category	Component description
Data Sources	
Static data	
Dynamic data	
Location data	
Data capturing devices	
Cloud	
Public	
Private	
Analytics	
Location Intelligence	
Integration and interoperability	
Application Programming Interface (API) Gateway	
Context Broker	
Enterprise Service Bus (ESB)	
Minimal Interoperability Mechanisms (MIMs)	
Platforms	
Digital Twin	
Urban Platform	
Other	
Formalised Ecosystems	
Open & Agile Smart Cities (OASC)[25]	
FIWARE[26]	
Open Geospatial Consortium (OGC)[27]	
Other	

[25] See the official web page of the Open & Agile Smart Cities (OASC) network, https://oascities.org/
[26] See the official web page of the FIWARE Foundation, https://www.fiware.org/
[27] See the official web page of the Open Geospatial Consortium (OGC), https://www.ogc.org/

3 Gathering insight on location intelligence in Smart Spaces

This section introduces the selection of case studies and their use cases. It also exemplifies the usage of the benchmarking framework by providing an analysis of the content of the case studies with regards to:

- the different roles of location intelligence,
- the different types of location intelligence and how it contributes to public value, and
- the various roles of the public sector.

3.1 Selection of case studies

The study aimed to identify cases with a specific focus on location intelligence and interoperability, in a variety of EU countries, with a specific focus on:

- Cases covering a variety of public services in a Smart Space, typically focusing in the smart city area, from which related services can emerge, such as smart transport or building management.
- Cases which are promising in terms of identifying interoperability inside and between Smart Spaces.

The outcome of the selection is a set of comparable and yet complementary case studies, providing insight into the varied landscape of interoperability approaches relating to Location Intelligence, digital twins, urban platforms, and IoT platforms and their ecosystems.

The four case studies cover a set of Smart City, and cross-Smart City use cases over a variety of geographic areas (Estonia (EE), Finland (FI); the Netherlands (NL); Portugal (PT); and Slovenia (SI)) in Europe. While not all cases are fully implemented – EE/FI, NL and SI are at proof-of-concept or Minimal Viable Product (MVP) stages - they all aim to develop innovation through public/private collaboration with a strong focus on user value. They provide varied approaches to the technical implementation and the standards' ecosystems. All case studies leverage a data infrastructure platform (e.g., an urban platform, an IoT platform). One case study is a fully mature system (PT), two case studies are in the innovation phase, exploring use cases through pilots and/or minimum viable products (SI, NL), while the fourth case study focuses on the interoperability between two urban platforms and the piloting of a specific geospatial standard for moving features connecting the two (EE, FI), including a cross-border dimension. The innovation case studies also provide insight into the collaboration approaches developed between the various public and private stakeholders.

Analysing this set of similar Smart Spaces (i.e., and Smart Cities) and their use cases through the Smart Space benchmarking framework provides insight into the diverse ways to implement them and the types of challenges they face. Further research can similarly explore other types of Smart Spaces, such as Smart Buildings.

3.1.1 FinEst Twins cross border feature (EE, FI)

The first case study that we selected is an application of the Urban Open Platform work package of the FinEst Twins project[28]. The project's goal is to pilot generic real-time data processing capabilities and provide a proof-of-concept implementation of a) cross-border geospatial models and b) implementation of the OGC Moving Features concept or a similar mechanism in the domain of Smart Mobility. Table 9 provides a general introduction.

[28] See the official project web page, https://www.finesttwins.eu

Table 9. FinEst Twins cross border feature case study description

<table>
<tr><th colspan="4">FinEst Twins cross border feature (EE, FI)</th></tr>
<tr><td colspan="2">Name
FINEST Twins: Crossborder Features</td><td colspan="2">URL https://www.finesttwins.eu</td></tr>
<tr><td colspan="2">Lead Organisation Name
Forum Virium Helsinki Oy</td><td colspan="2">Lead Organisation Category
Non-profit company owned by the city of Helsinki</td></tr>
<tr><td colspan="4">Description
The FinEst Twins project is building a FinEst Centre for Smart Cities based in Estonia and establishing a partnership with their Helsinki region counterparts. The FinEst Centre develops the cross-border knowledge transfer infrastructure (Urban Operating Platform) through real-life pilots. The FinEst Twins develops a use case for modelling a ferry transfer from Helsinki, Finland, to Tallinn, Estonia. When modelling the ferry as a geospatial feature, potential attributes such as energy consumption, passenger count, and scheduled arrival time are identified.</td></tr>
<tr><td>Administrative level
Sub-national, City</td><td>Geographic coverage
Finland, Estonia</td><td>Start Date
1.12.2019</td><td>Still Active
Yes</td></tr>
</table>

One of the main drivers of the implementation is the role of geospatial data to define the context of the operational and analytical data. It is estimated that in the public sector, over 80% of the created data is spatial by nature[29], but often smart city platforms do not support well the spatial nature of the data context.

In many cities, digital twins have arisen as a tool to provide new ways of providing situational awareness and transparency within the organisation and towards the citizens. Digital Twins are based on semantic, geospatial data models that can create new types of context to features by adding static and dynamic attributes such as energy meter readings from buildings. In addition to dynamic attributes on existing features, there are use cases for dynamic features. This refers to situations where an object would appear on a geospatial data model and possibly move on a set trajectory. This kind of use case can be related to transportation or logistics.

Since the detailed geospatial models typically focus on a specific area such as a city, cross-border cases involve requirements where such moving features can "travel" from one geospatial model to another. In FinEst Twins, an example is a use case for modelling a ferry transfer from Helsinki, Finland, to Tallinn, Estonia (see Figure 5). When modelling the ferry as a geospatial feature, potential attributes such as energy consumption, passenger count and scheduled time or arrival are identified. The standardisation of Moving Features is currently in process at the Open Geospatial Consortium (OGC). Some pilots have defined a data API, but there is still a need for experimentation and new pilots. The business case of moving features can be related to Smart Mobility, tourism or logistics, and the information required for the pilot is already available as open data.

[29] See discussion of this classic statement, https://www.gislounge.com/80-percent-data-is-geographic/

Figure 5. Screenshot[30]: pilot on a ferry transfer from Helsinki to Tallinn

In summary, the FinEst Twins explore cross-border location interoperability, a key focus of the ELISE Action.

3.1.2 The Digital City of Rotterdam (NL)

The Municipality of Rotterdam is investigating the possibilities for the future city in the Digital City program. The core of this program is the development of a digital Open Urban Platform with a 3D Digital Twin of Rotterdam, in which all fixed physical objects (houses, trees, benches, etc.) in the city are included. An introduction is provided in Table 10.

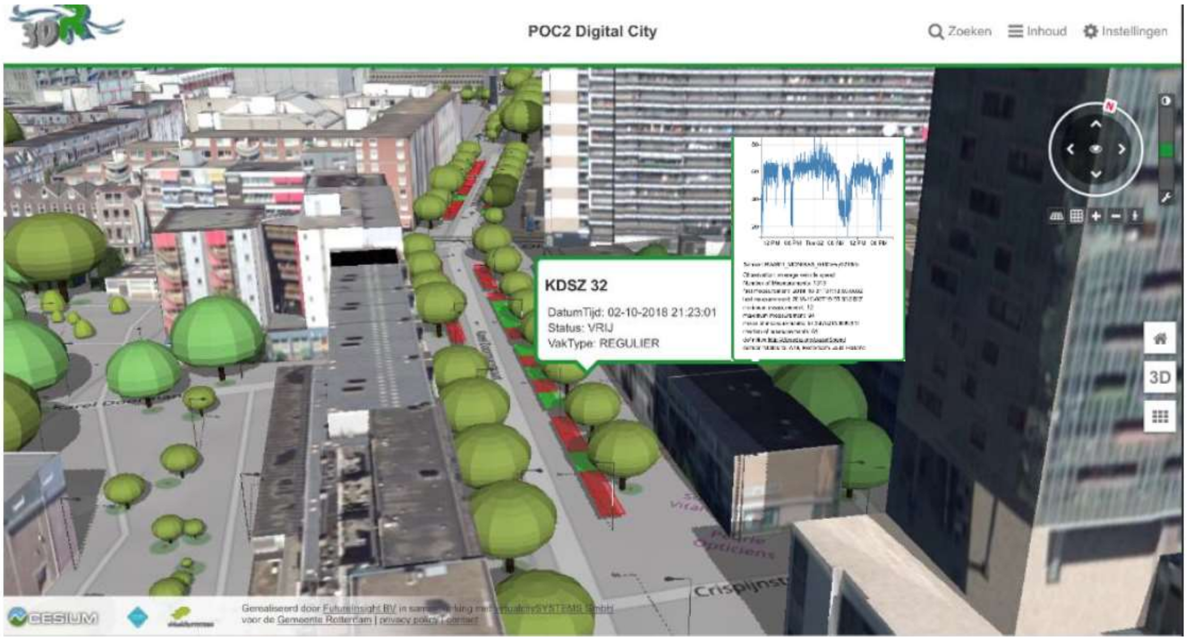
Table 10. Digital City of Rotterdam case study description

<table>
<tr><th colspan="4">The Digital City of Rotterdam (NL)</th></tr>
<tr><td colspan="2">Name
Rotterdam Digital City</td><td colspan="2">URL
https://www.rotterdam.nl/wonen-leven/digitaal/</td></tr>
<tr><td colspan="2">Lead Organisation Name
Gemeente Rotterdam</td><td colspan="2">Lead Organisation Category
Governmental</td></tr>
<tr><td colspan="4">Description
The Municipality of Rotterdam is investigating the possibilities for the future city in the Digital City program. The core of this program is the development of a digital Open Urban Platform with a 3D Digital Twin of Rotterdam. Knowledge is now being gained through projects and pilots to further stimulate these developments.</td></tr>
<tr><td>Administrative level
Sub-national, City</td><td>Geographic coverage
The Netherlands</td><td>Start Date
2017</td><td>Still Active
Yes</td></tr>
</table>

The model used here is supplemented with 'live' data about the use of the city, answering questions, such as: is that lamppost lighting on? Is that parking bay occupied? Is that waste container full? This digital image of the reality forms a foundation for numerous intelligent applications and offers all of them the same reality. Figure 6 provides an impression.

[30] See the live system, https://proto.fvh.io/

Figure 6. Screenshot[31]: Digital Twin of Rotterdam



Knowledge is now being gained through projects and pilots to further stimulate these developments. Specific use cases focus on integrating Building Information Models (BIM) with geospatial models, which will provide insight into the interoperability challenges across different types of Smart Spaces.

The city-scale digital twin model is created using data sourced from a multitude of data streams, including IoT sensors and geospatial technologies such as LIDAR (LIght Detection And Ranging), Drones, etc. The data collected from these sources were integrated into CAD/BIM software. Artificial intelligence was used to process the data and depict the city's current reality to improve the urban planning process radically. As a result, the current system supports a rich set of diverse use cases.

The **"spatial planning 3D gaming" use case** is an application to enable time and location independent participation and consultation in spatial planning. In a 3D game setting, parties can think about the structure of an area concerning potential restrictions, e.g. costs and physical obstacles. The objective is that residents can shortly make proposals themselves and submit them to the municipality, and they can also see their designs 'come to life' with augmented reality.

The **"integrated environmental permit" use case** is a prototype for the automation of an integrated environmental permit by making use of 3D models (BIM and geo) and data-driven rules (instead of text typed rules). By rendering some of the criteria transparent in a 3D model, the chance of a successful proposal increases and can be assessed more quickly.

The "**SAFE 3D physical safety of people near and in buildings" use case** is a prototype to increase the physical safety in and around buildings and the real-time presence of people. The objective is to arrive at a better safety policy with specific information.

The "**3D building information and augmented reality (AR)" use case** is an application to use 3D building information (BIM) for communication and promotion purposes on building projects. With AR, the proposed final results can already be rendered visible before and during the building project. Passers-by can then scan a code at the building site and experience the scheduled building in its actual size relative to the surrounding environment on their smartphone.

On top of the above, the following three new pilots are being developed, but they will not be part of this case study as they are in the making.

- Digital Twin[32] for sustainability;

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31 Source: Documentation provided by the City of Rotterdam.
32 It is important to note that these are not separate twins, but only different views on the same Digital Twin.

- Digital Twin[33] underwater; and
- New data sources making the City data-driven. It is important not only to look at smart applications but also at good, generic, scalable and maintained data sources.

In summary, this Digital City of Rotterdam case study explores new areas for ELISE, namely convergence of the GEO and BIM worlds.

3.1.3 The Urban Platform of the city of Guimarães (PT)

The Guimarães City Council, through the Division of Intelligent and Information Systems, is implementing an Urban Intelligence Platform to obtain answers to daily challenges through digitalisation, based on data collected in an urban environment. Table 11 provides the basics.

Table 11. The Urban Platform of Guimarães case study description

<table>
<tr><th colspan="4">The Urban Platform of the city of Guimarães (PT)</th></tr>
<tr><td colspan="2">Name

Urban platform of Guimarães</td><td colspan="2">URL

https://www.ubiwhere.com/en/news/ubiwhere-established-the-urban-platform-in-guimaraes-a-good-practice-supported-by-the-european-commission</td></tr>
<tr><td colspan="2">Lead Organisation Name

Ubiwhere</td><td colspan="2">Lead Organisation Category

Private sector</td></tr>
<tr><td colspan="4">Description

The Urban Platform offers Guimarães a city dashboard that presents information, updated in real-time, from different domains and several sources such as sensors, platforms, services, and even the citizens themselves. It supports novel features for operational activities such as faster response to road accidents, bidirectional communication with the community, traffic flow improvement and parking area optimisation. By integrating these sources of information and harmonising the data, the analysis opportunities are noticed in real-time, enabling reliable decisions.</td></tr>
<tr><td>Administrative level

Sub-national, City</td><td>Geographic coverage

Portugal</td><td>Start Date

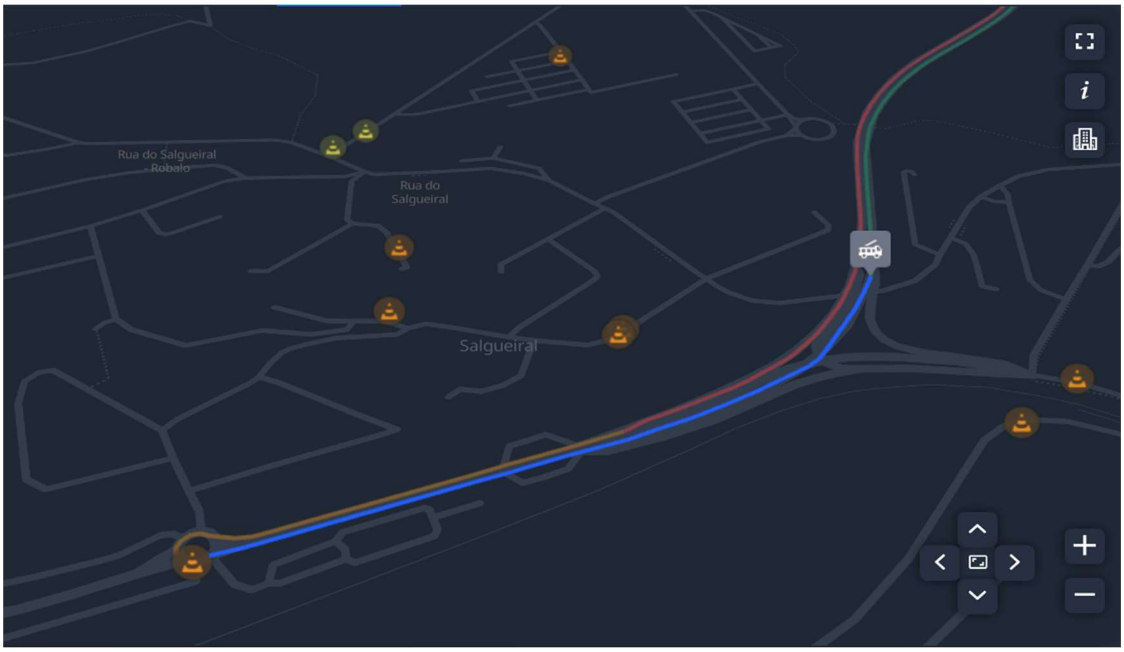
2019</td><td>Still Active

Yes</td></tr>
</table>

Again, we zoom into a rich set of use cases to better understand the approach. The “**efficient route planning” use case** leverages location data (road attributes, points of interest, etc.) to add context to its planning. This feature also considers dynamic information (such as real-time traffic information, road incidents and closures, parking occupancy, etc.) to calculate the most efficient route between two points (origin and destination). The figure below provides an impression.

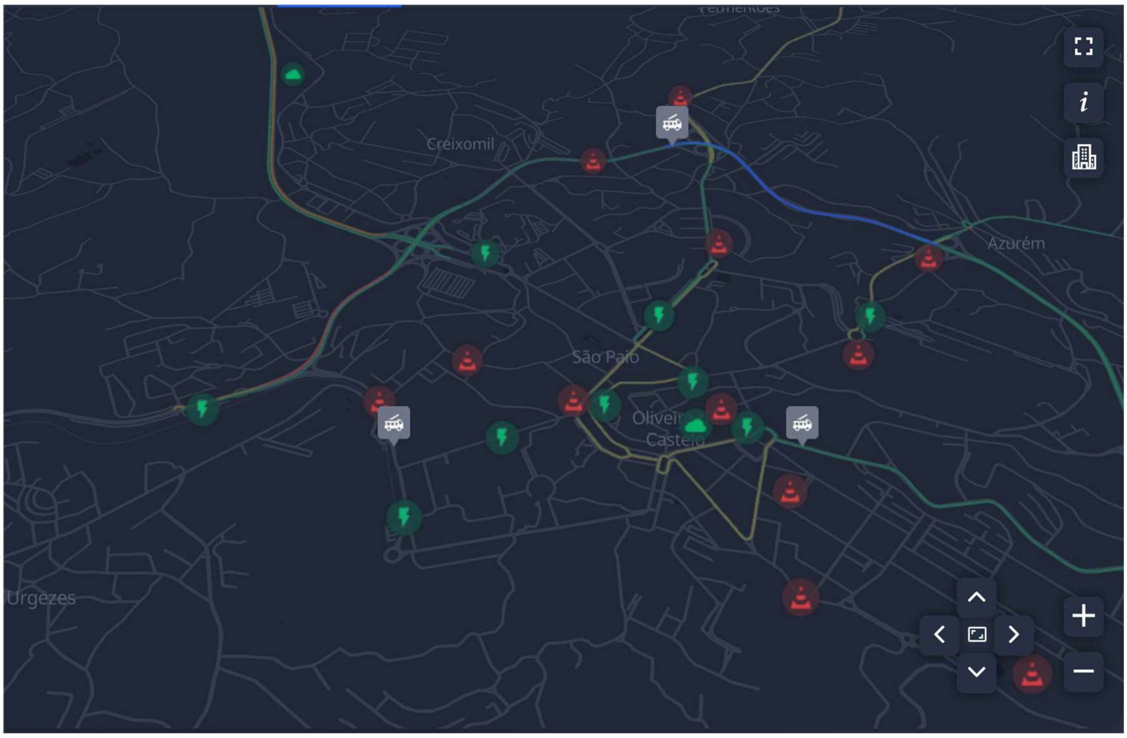
[33] idem

Figure 7. Screenshot:[34] Guimarães efficient route planning use case



The "**real-time vehicle location tracking**" provides real-time location information of vehicle fleets to assess their mobility performance, correlate with incidents and improve the efficiency of operations of public authorities and first responders (through matching and recommendation systems). Again, we provide a visual impression below (Figure 8).

Figure 8. Screenshot: Guimarães real-time vehicle location tracking use case



[34] Source: Documentation provided by Ubiwhere.

The "**disasters/catastrophe management & response use case"** aims to assist in managing and decision-making in cases of emergencies such as fires, floods, earthquakes by leveraging on location data to add context about the most affected places and identifying consequences, such as destroyed houses, fallen trees, power poles, blocked bridges, etc. A specific incident in this use case is a point of interest that works as a destination in the Efficient Route Planning use case while also leveraging the closest vehicle unit thanks to location data from the Real-Time Vehicle Location Tracking use case that we depicted above.

Overall, this case study builds on previous ELISE work, which focused on Location Intelligence[35], data sources, challenges and opportunities.

3.1.4 Pametna Mlaka (SI)

The City Council of Kranj made a call to action for companies to develop pilots for innovative smart city solutions. The Smart Mlaka (Pametna Mlaka) pilot is a cooperation between regional companies. Table 12 summarises the most central information.

Table 12. Pametna Mlaka case study description

Pametna Mlaka (SI)			
Name Smart neighbourhood Mlaka of city of Kranj		URL https://www.youtube.com/watch?v=HbclFfj9lkw	
Lead Organisation Name 3fs (technical lead), Riko (infrastructure company – coordinator and project lead), Municipality of Kranj		Lead Organisation Category Private-public sectors	
Description The City council of Kranj has created a business playground with a straightforward call to action: "innovative companies, we are here to lower the barriers of innovation and integration for you to develop your smart city concepts and solutions ready for the future". The result is a "public cloud first" smart city solution, developed lean and agile and in a symbiotic relationship between the city council and IoT innovation companies.			
Administrative level Sub-national, City	Geographic coverage Slovenia, Gorenjska region	Start Date 2020	Still Active Yes

The current version of Smart Mlaka is a comprehensive MVP (minimum viable product) of Smart city IoT platform, which aggregates data from various sources – electricity, water, gas, traffic (max speed, average speed – by vehicle category), environment (air temperature, air pressure, air humidity, wind direction, wind speed, NO2, O3, PM10, PM25, PM100, noise). This platform enables the following:

- Data aggregation and consolidation;
- Technology-agnostic integrations via standardised APIs and brokers (FIWARE-NGSI v2[36]);
- Smart Services which can use machine learning and other AI technologies such as predictive analytics or smart alerting;
- Innovative services such as Digital Twin; and
- Future user/citizen empowerment, engagement and gamification.

This innovation pilot aims to use solutions and feedback on the MVP from its limited scope (neighbourhood of Mlaka) and then spread it across the city and region in a lean and agile way. Smart Mlaka uses location-related

35 The presentation of the case studies through a recorded webinar is available on Joinup, https://joinup.ec.europa.eu/collection/elise-european-location-interoperability-solutions-e-government/event/elise-webinar-location-intelligence-technology-trends-and-case-studies-digital-government

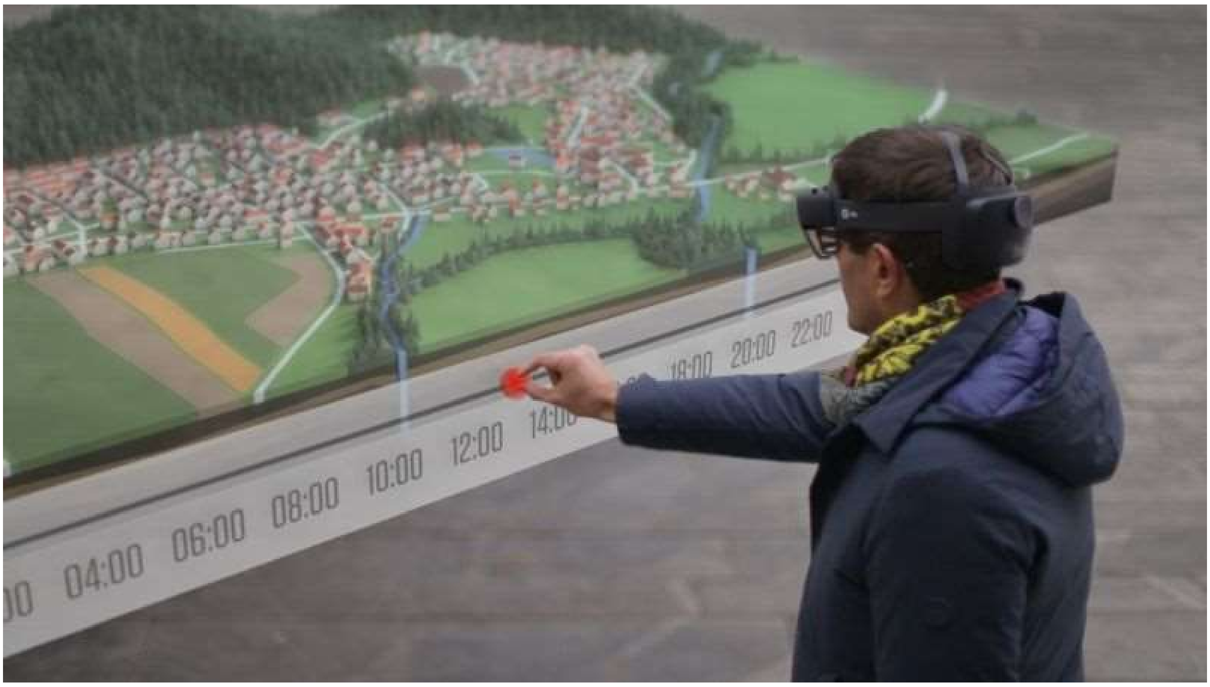
36 FIWARE Core Context Management, see also https://fiware-tutorials.readthedocs.io/en/stable/getting-started/index.html

data to provide real-time overview and insights into urban areas. For now, all data providers or metering points (usually sensors) are stationary; latitude and longitude are specified in a central catalogue.

The use case of “**Digital twin proof of concept through augmented reality**” allows the user to observe all the data inputs in a 3D model of the city, including how weather and time affect the visual presentations. The user can also “drag” the timeline into the future.

A digital twin is manifested through Augmented Reality technology using the Microsoft Hololens 2 device (see Figures 9 and 10). This digital twin relies on the 3fs proprietary digital twin platform and an AR CI/CD pipeline called AWAKE (https://awake.health/) and uses the Smart Mlaka platform as the data source. The graphical aspect relies heavily on cadastre data.

Figure 9. Screenshot[37]: Pametna Mlaka Digital twin proof of concept through augmented reality use case 1/2



The use case “**map-based dashboard with predictive and reference point capabilities**” provides a web and mobile-ready dashboard demonstrating the complete capability of data ingestion, transformation, analytics and prediction. The dashboard was developed in the most agile and cost-efficient way, relying heavily on building blocks provided by the chosen public cloud. The public cloud offering was also used for elements of machine learning that enable the user to drag the timeline into the future (and predict, for example, temperature estimations, electricity consumption or CO2 emissions). Figures 11 and 12 provide impressions of the graphical user interface.

[37] Source: Documentation provided by 3fs.

Figure 10. Screenshot[38]: Pametna Mlaka Digital twin proof of concept through augmented reality use case 2/2

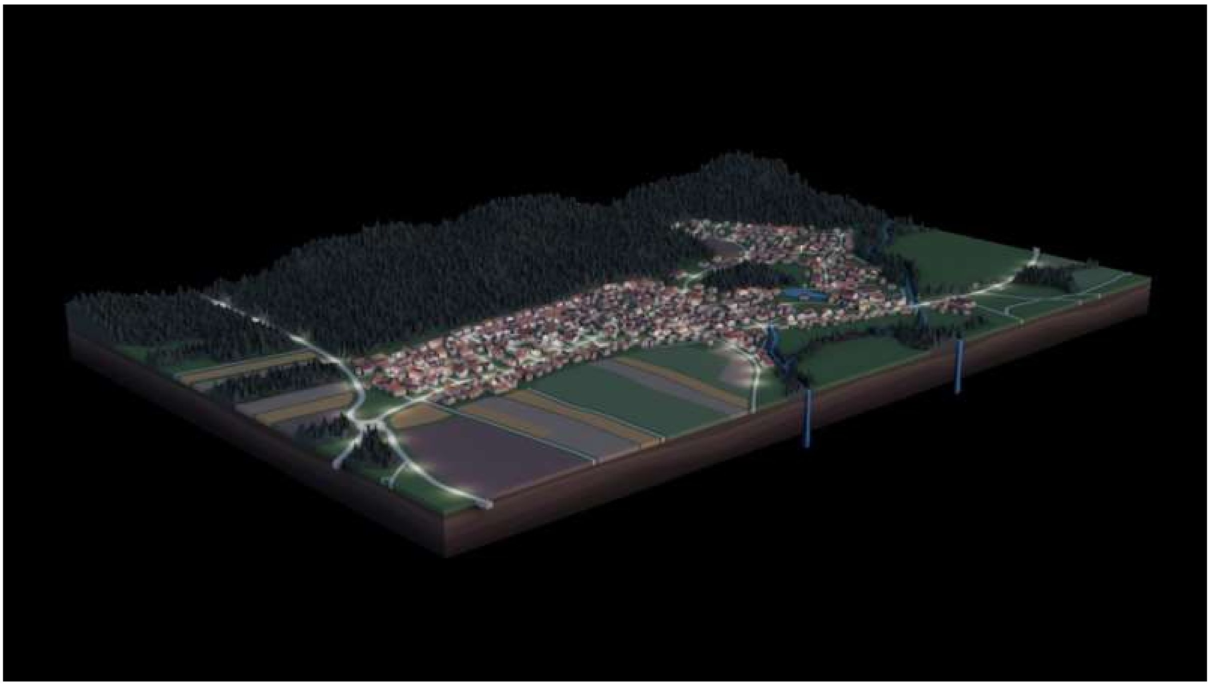
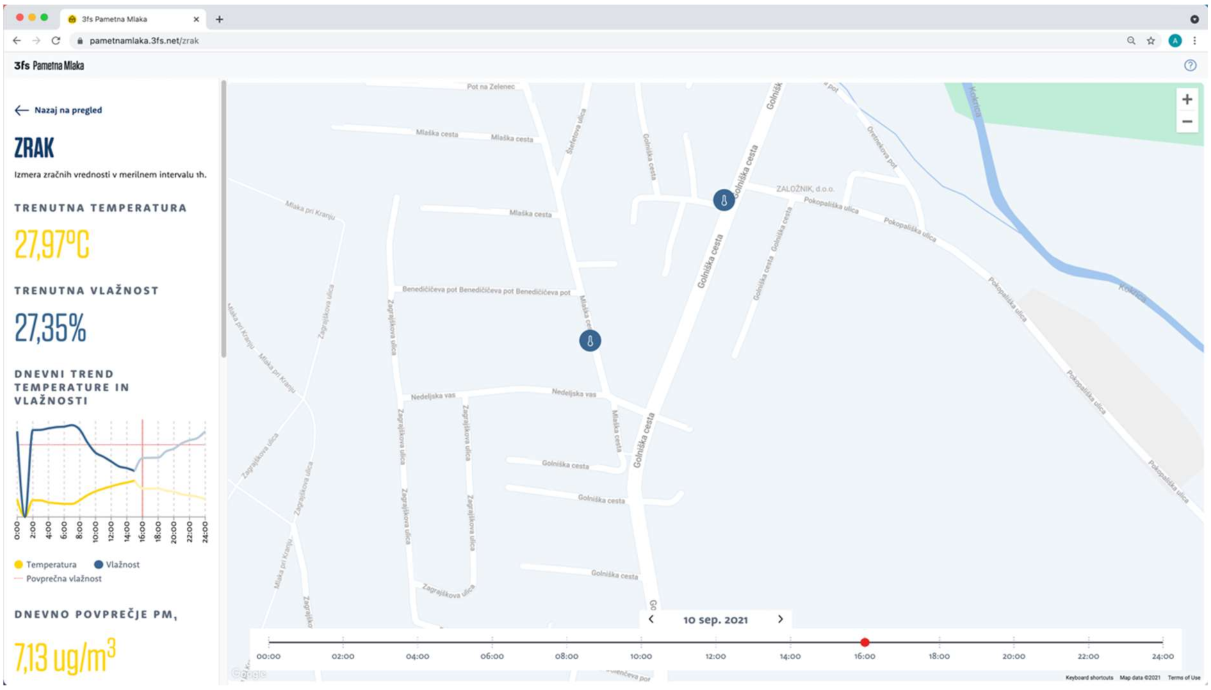
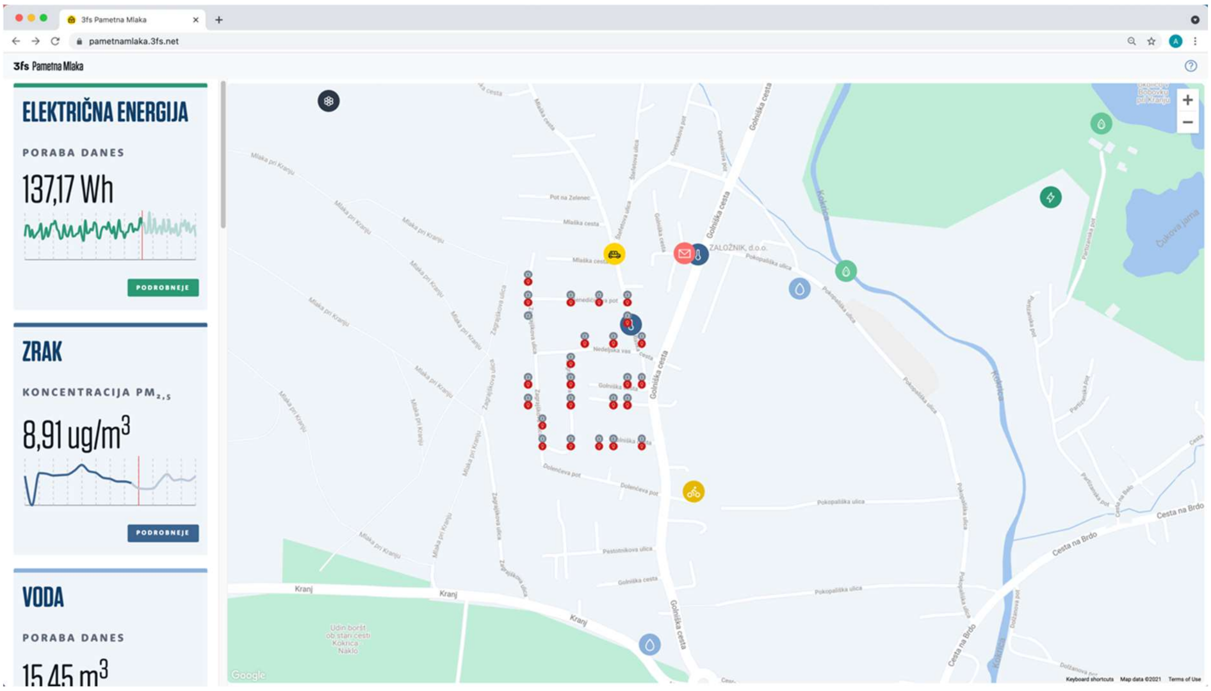


Figure 11. Screenshot[39]: Pametna Mlaka dashboard with predictive and reference point capabilities use case 1/2



38 idem
39 idem

Figure 12. Screenshot[40]: Pametna Mlaka dashboard with predictive and reference point capabilities use case 2/2



In summary, this case study focuses on innovation spurred by the private sector and is a leading case of Smart Spaces in the country. ELISE has a particular interest because of the focus on IoT and augmented reality, expanding in new areas.

3.2 Analysis of the selected case studies

This section provides an analysis of the four dimensions (as introduced in Section 2.3), focusing on the role of location intelligence and the way it contributes to the notions of public value in Smart Spaces. The complete case studies are provided as annexes to this report - covering all details of the framework dimensions and following the template introduced in Section 2.4.

3.2.1 The role of location intelligence in Smart Spaces

We analyse the use of location intelligence in a Smart Space following the various roles of location data that we identified in the case studies:

- Location data is the service,
- Location data adds intelligence, and
- Location data supports data validation activities.

The analysis is further detailed within the four steps of the data value chain (as introduced in Section 2.4):

- Generation: data acquisition (information is captured in a digital format from devices).
- Collection: data organisation (collection and consolidation of data from multiple sources, which also comprises checking the data accuracy before integration into a valid dataset).
- Processing: data processing and analysis (data processing to generate insight using identification of patterns in the data, including descriptive, predictive and prescriptive analytics).
- Exchange: data sharing and publishing (data is shared and published through APIs, data portals; at this stage, it can also be reused or repurposed). Re-users of data will either embed the data into their data stores as part of their data collection activities or use the data immediately in their processing activities. Thus, the network effect of promulgated data sharing and reuse develops, and value is extended.

[40] idem

3.2.1.1 Location data is the service

Location data *is the service* in a Smart Space when location data or location intelligence algorithms are the main value-generating component of a service, for example, in a navigation service.

Table 13 details the way location data is the service in the various steps of the value chain, using the examples provided by our four case studies.

Location intelligence provides value in each of these steps by being an essential element supporting the activities that develop data into assets.

Table 13. Location data is the service across the data value chain

Location data is the service	Generation	Collection	Processing	Exchange
(EE, FI) The FinEst Twins cross-border feature uses location data from the CityGML city models from Helsinki and Tallinn and the maritime traffic API from the Finish transportation authority at the collection stage. This data is then processed/integrated so that the maritime data is converted into the feature's location.		X	X	
(NL) The Digital City of Rotterdam aims to ensure that all data in the Smart Space has a location-based element; in most cases, there is a location element such as an address (typed). Although not all data is geo-coded, the important generic registries are.	X	X	X	X
(PT) The Urban Platform of Guimarães: Location data is the service at the collection and exchange stages to identify the real-time vehicle location or some occurrence/catastrophe that took place. To develop an efficient route between a vehicle location and incident (disaster), other information about traffic congestions and road incidents or roadworks (and their location) are considered in the itinerary's dynamic planning. At collection stage: Matching road segment attributes (no. lanes, pavement, authorised vehicles, speed rules) with other data (traffic flow, incidents). At processing stage: Information is linked to its geographic context (e.g. road segment, POI, building, parish, district, etc.) both at the edge and the cloud to identify the right stakeholder to invoke (both geographically and politically) and determine the potential priority in responding. At exchange stage: Making the road conditions data available to the community through open APIs and/or open data portals.		X	X	X
(SI) Pametna Mlaka: at the generation stage, location data is a key platform component. The location of all metering points is currently pre-configured in a central catalogue. At collection stage: Metering points are sending data using various technologies (AMQP, MQTT, etc.). All measurements include metadata with meter ID which is used to resolve specific location data.	X	X	X	X

Location data is the service	Generation	Collection	Processing	Exchange
At processing stage: Current processing of location-based data is done through data consolidation and statistics services (SUM, MAX, AVG, etc.). At exchange stage: Location-based data is available through APIs on the developer's portal as well as solutions (Digital Twin, Map based dashboard).				

3.2.1.2 Location data adds intelligence

Location data or location intelligence algorithms can also enrich the value generated by products or services, such as location-based advertising. Location intelligence algorithms can also help analyse location data to make the product or service offering more intelligent, for example, in the shortest route calculation.

The table below (Table 14) details how location data adds intelligence in the various value chain steps, again benefitting from examples identified within the case studies. It shows that location intelligence has a role in developing data into assets in two value chain steps. The value chain steps impacted are constrained to the processing and exchange activities, which is logical due to the nature of these steps.

Table 14. Location data adds intelligence across the data value chain

Location data adds intelligence	Generation	Collection	Processing	Exchange
(EE, FI) The FinEst Twins pilot is conceived to enable the delivery of the Estimated Time of Arrival in the future (exchange stage).			X	X
(NL) The Digital City of Rotterdam uses location data to process information – identifying where are the bins located, for example (processing stage).			X	
(PT) The Urban Platform of Guimaraes links information to its geographic context (e.g. road segment, POI, building, parish, district, etc.) both at the edge and the cloud to identify the right stakeholder to invoke (both geographically and operationally) and determine the potential priority in responding (processing stage).			X	
(SI) Pametna Mlaka: at the processing stage, the data processing pipelines use baseline machine learning and other AI technologies to enable smart alerting in real-time and baseline predictivity of sensor data. At exchange stage: Smart features like aggregated context-aware data alerting hooks can be exposed through APIs and solutions through the API/developer portal.			X	X

3.2.1.3 Location data supports data validation activities

Location data is used to validate other sets of data, as, for example, location data in lampposts validate earthquake information identified by other sensors. Also here, the table below presents concrete findings from the four case studies that were analysed as part of this work.

Table 15. Location data supports data validation activities across the data value chain

Location data supports data validation activities	**Generation**	**Collection**	**Processing**	**Exchange**
(PT) The Urban Platform of Guimaraes, at the generation stage, captures catastrophe data (e.g. temperature and pollutant sensors or cameras for wildfires, accelerometer for earthquakes) with geolocated sensors that provide information in real-time. At the processing stage, geolocated sensors are linked to computing units in street furniture (e.g. lampposts) at the edge that pre-validate and raise alarms to ensure a proper response.	X		X	
(SI) Pametna Mlaka: at the generation stage, multiple geolocated metering points/sensors send data, including their location, in "real-time". At the processing stage: Data from multiple geolocated metering points/sensors can be crosschecked to ensure data validity. The processed information can then also be verified by other external services. At exchange stage: To ensure information validity and accuracy, raw data can also be retrieved using APIs by 3rd party clients.	X		X	X

3.2.2 Location intelligence in Smart Spaces, its impact and its contribution to public value

This section details the location intelligence type used for each use case analysed in the four case studies. Here, we distinguish between:

- descriptive analytics that uses data to describe, summarise and visualise information, as well as mining and aggregating current and historical data to gain insight;
- predictive analytics that uses machine learning with data to make predictions and uses statistical and probabilistic techniques to predict future trends and outcomes; and
- prescriptive analytics that recommends courses of action to achieve an outcome by making decisions.

This section also provides insight into how location intelligence has an impact on the type of decision making, which can be either "Strategic" – i.e., it refers to a strategic decision such as where to place a building, or "End-user" – i.e., it refers to the functionality provided to the end-user such as route recommendations.

It also identifies if this impact is:

- long-term, i.e. the decision has a high economic and/or timely impact, with the decisions, for example, implying a significant investment, and/or is expected to last from a few months to years (for example, constructing a new building);
- mid-term, i.e. the decision has a high economic and/or timely impact, with the decisions, for example, implying a moderate investment, and/or is expected to last from days to months (for example, adjusting distribution routes); or
- short-term, i.e. the decision has a small economic and/or timely impact, the decision is made immediately, has a low individual cost and is expected to last from minutes to days (for example, optimisation of waste disposal).

In addition, the section also analyses how the use cases contribute to public value. Public value is categorised as follows:

- Economic and financial value, which includes efficiency, cost optimisation and new sources of revenue e.g. data monetisation.
- Citizen value and user attractiveness, which includes social and environmental sustainability, user friendliness.
- Administrative value and effectiveness including improving, innovating, and/or delivering in a high-quality manner.
- Democratic value and trust, which includes increased transparency.

The analysis is compiled into one table below (Table 16), providing a mapping for each use case and applying these dimensions: location intelligence, decision making and impact, and public value generated.

Notably, the value assessments (low, medium and high) are made relative to each use case, so they are not necessarily comparable across use cases. The definitions provided in Section 2.3 have been followed in the assessments.

Table 16. The type of location intelligence in Smart Spaces, its impact and its contribution to public value

Use cases	**Location intelligence type**	**Decision making**	**Impact**	**Economic and financial value (Inc. Efficiency)**	**Citizen value and user attractiveness (incl. Social, environmental sustainability)**	**Administrative value and effectiveness (incl. innovation and quality)**	**Democratic value and trust (incl. Transparency)**
(FI,EE) Cross-border maritime information	Descriptive Predictive	End-user	Short term	Medium	High	Medium	High
(NL) Spatial Planning 3D gaming	Descriptive	End-user Strategic	Medium term	Medium	High	High	High
(NL) Integrated environmental permit	Descriptive	End-user	Medium term	Medium	High	High	Medium
(NL) SAFE 3D Physical safety of people near and in buildings	Descriptive Predictive	End-user	Medium term	Medium	High	High	Medium
(NL) 3D Building Information and AR	Descriptive Predictive	Strategic	Long term	Low	High	Medium	High
(PT) Efficient Route Planning	Descriptive Predictive Prescriptive	Strategic	Short term	Medium	High	High	High
(PT) Real Time Vehicle Location tracking	Descriptive Predictive Prescriptive	Strategic	Short term	High	Low	High	Low
(PT) Disasters/ Catastrophe Management & Response	Descriptive Predictive Prescriptive	End user	Short term	High	High	High	High

Use cases	Location intelligence type	Decision making	Impact	Economic and financial value (Inc. Efficiency)	Citizen value and user attractiveness (incl. Social, environmental sustainability)	Administrative value and effectiveness (incl. innovation and quality)	Democratic value and trust (incl. Transparency)
(SI) Digital twin POC through augmented reality	Descriptive Predictive	Strategic	Long term	Low (for the citizen)	High	Low	None (currently, only 3 devices)
(SI) Map-based dashboard with ML prediction	Descriptive Predictive	Strategic	Long term	Medium	Low	High	Medium

The use case analysis shows that location intelligence provides a wide range of types of insight: for making strategic and end-user decisions that have various levels of impact - short, medium or long term.

Location intelligence provides insight through various types of analytics: descriptive, predictive or prescriptive, and these different types of insight all contribute to public value, with a slightly stronger contribution to **citizen value and user attractiveness** (which includes social and environmental sustainability and user-friendliness), as well as, **administrative value and effectiveness** (which includes improving, innovating and/or delivering in a high-quality manner).

Overall, there is **a strong case for location intelligence of public services**, as demonstrated in this section with the analysis of the insight generated, its impact and its contribution to public value.

3.2.3 The various roles of the public sector in the data value chain

The public sector plays a varied and strong role in relation to location intelligence in Smart Spaces, including roles such as data provider, consumer, broker, or owner. The public sector also plays a role in enforcing or supporting standardisation initiatives, which impact the Smart Spaces. These roles are analysed along the data value chain in the case studies, and this section provides a synthesis. The details are again provided in the annexes.

The public sector as data provider

The case studies illustrate that the public sector can act as a **data provider** in various ways. In the data generation stage, the public sector can provide cadastre data (seen in the cases of EE and FI). It can also acquire data capturing systems, such as sensors or meters (seen in the cases of PT and SI).

The role of the data provider at the collection step was not specified in the case studies, except that the public sector can provide data through the base registries throughout the complete value chain (seen in the case of NL).

The public sector can provide data collected from other sources to be processed in the Smart Space in the processing step. For example, in the FinEst case study (EE, FI), data about ships is provided by the maritime authority, and it is then processed in the platform by the platform owner (the private company owned by the city of Helsinki). In another case study (SI), the municipality provides the data, which is then processed on the platform that it owns. In the urban platform case (PT), the public sector allows other stakeholders to process its data. In this case, data is shared by the public sector, ensuring privacy best practices (PT) (anonymisation of sensitive information through hashing and trimming and limiting time periods of access).

At the exchange step, the public sector ensures data is accessible using open standard data interfaces (PT) - for example, using APIs or sending it to the government public data portal (SI).

The public sector as data consumer

The role of the public sector as a **data consumer** is also well represented in the case studies. In one case study (NL), the public sector is expected to consume location data through the platform in all value chain steps. More specifically, we also see how it can consume data at the processing step by processing data while using privacy-preserving mechanisms and tools (PT, SI). The consumption can be supported using APIs (SI).

At the exchange step, the public sector, as the platform owner, ensures access to the data is given to other public sector stakeholders to consume the data (PT). This can be done in a secured manner if necessary (SI) with authorised and authenticated public sector data consumers retrieving pre-defined sets of data using security mechanisms and end-to-end encryption.

The public sector as data broker

The role of the public sector as **data broker** is limited to providing access to the data at the exchange step, similarly to its role as a data provider (PT, SI). The notion of data broker is a trend in the transportation sector (EE, FI), relating to the concept of MaaS[41] (mobility as a service), but the role of data broker is foreseen mostly for the private sector, and it is not yet implemented widely.

Feedback in the case study development phase reflected on the role of the public sector - rather than data broker –as data market "master" (NL). In the latter, the public sector is the intermediary party in case of conflict among various stakeholders in an ecosystem, which enforces the respect of public value principles in the management of the Smart Spaces and the related data.

The public sector as data owner

The role of the public sector as **data owner** was added during the case study development phase. The feedback collected (NL) related to the importance of the data being owned by the public sector as an outcome of a Smart Space implementation with strong involvement of the public sector, such as in a Smart city / Urban Platform. The ownership of the solution or platform does not necessarily imply ownership and access to the data. In the case where the municipality is the owner of the platform (SI), the concepts of "data exit strategy" and "data lock-in avoidance" are an important dimension discussed.

The public sector as data supporting or enforcing standardisation

The public sector plays a strong role in **supporting and enforcing standardisation** through procurement (PT, SI), with the public authorities requiring open standards (typically FIWARE's NGSI-LD[42]). The procurement of open data (NL) enforces a common language of receiving and releasing data. Procurement encourages/enforces interoperability best practices, such as (NL) the usage of MIMs[43] and PPIs[44]. Using open standards is recommended in research projects funded by the EU. The OGC Moving features SWG[45] is leveraged in one of the case studies (EE, FI). The public sector participates in the OGC Standards Working Group (SWG), especially the government of Japan.

However, at the level of the case studies, the involvement of public sector stakeholders in the standardisation ecosystems is not identified. The private sector can play a stronger role there. For example, Ubiwhere (PT), was part of the Synchronicity project where it helped OASC create the MIMs, and the Urban Platform is today part of the CityxCity Catalogue[46] as one of the examples of solutions compliant with OASC MIMs. Ubiwhere is not yet an official partner of OASC. Ubiwhere is a member of the FIWARE Foundation[47]. Ubiwhere is a full member of ETSI, having joined in 2017 to contribute to the industry with its R&D results in the format of specifications and use cases and share its telecom and smart cities know-how and perspectives concretely in industry

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41 Mobility-as-a-Service (MaaS) is an emerging type of service that, through a joint digital channel enables users to plan, book, and pay for multiple types of mobility service, see Mladenović, M.N. (2021), Mobility as a Service, International Encyclopedia of Transportation. pp. 12–18, https://www.sciencedirect.com/science/article/pii/B9780081026717106074?via%3Dihub

42 For the detailed specification, see https://www.etsi.org/deliver/etsi_gs/CIM/001_099/006/01.01.01_60/gs_CIM006v010101p.pdf

43 Minimal Interoperability Mechanisms (MIMs): the minimal common technical ground needed in a global market for IoT-enabled services for cities and communities, for more details, see https://oascities.org/minimal-interoperability-mechanisms/

44 Identifying a set of principles for common interfaces (PPI, Pivotal Point of Interoperability) to ensure interoperability also in case of absence of standards or misalignment of available standards, for more details, see https://oascities.org/wp-content/uploads/2018/06/DI224-033-v1-IES-City-IoTWeek2018.pdf

45 See OGC's Moving Features Standards Working Group (SWG), https://www.ogc.org/projects/groups/movfeatswg

46 See Ubiwhere's urban platform catalogue, https://catalogue.city/en/products/urban-platform-a-single-integrated-view-of-our-smart-cities

47 See impact story captured by FIWARE, https://www.fiware.org/wp-content/uploads/FF_ImpactStories_Ubiwhere.pdf

specification groups[48]. Ubiwhere has been collaborating in four Specialist Task Forces linked with its domains of expertise[49].

On the other hand, the involvement of the public sector in the standardisation process and ecosystem at the EU level is done, for example, with the EU[50] involvement with ETSI for the standard on Context Information Management API (FIWARE NGSI v2 and FIWARE-NGSI-LD, respectively) - used in the case studies (PT, and potentially in NL in the future). INSPIRE data specifications – also used in the case studies (NL, SI) - were created collaboratively by EU public administrations, coordinated by the European Commission - DG Environment, Eurostat (the statistical office of the European Union) and the JRC.

In summary, we may conclude that - for the public sector - the roles of data provider and data consumer seem common across the value chain. From the cases that we examined, the role of data broker for the public sector appears limited to providing access to the data at the exchange step, similarly to its role as data provider. However, there is room in the Smart Space ecosystem for a role for the public sector as data market "master", enforcing the respect of public value principles in managing the Smart Spaces and the related data. Finally, ownership of the data by the public sector is important, although this can have implications to be clarified by proper data governance.

As for its role regarding standardisation activities and requesting, through procurement, the usage of standards, the public sector takes part in standardisation processes. Although this was not identified in the case studies' public sector organisations, they promote standards that the European Commission supports.

[48] Examples include CIM (Cross-cutting Context Information Management), MEC (Multi-Access Edge Computing), ZSM (Zero touch network & Service Management) and OSM (Open Source MANO).

[49] More specifically, STF561 (Smart cities and communities: standardisation to meet citizen and consumer requirements), STF551 (MEC Testing Framework) and STF569 (Testing Framework for Multi-Access Edge Computing) and STF584 (Artificial Intelligence for IoT Systems).

[50] See overview page at the Connecting Europe Facility (CEF), https://ec.europa.eu/cefdigital/wiki/display/CEFDIGITAL/EU+Standards

4 Improving the use of location intelligence in Smart Spaces

In this section, we benchmark the barriers and enablers to the market uptake in the four case studies and analyse related public sector actions to derive a set of **five areas** where the public sector can act to lower the barriers of implementing Smart Spaces. Again, the details from the case studies are provided in the annex of this report.

4.1 Funding and financing of Smart Spaces

The lack of funding is cited on several occasions in the case studies, with enablers being **public funding**, such as funding research for developing proofs-of-concept (EE, FI) and private funding from innovation research budgets supporting the development of minimal viable products (SI)[51]. To address related issues, **public-private partnerships** are identified as best practices for public sector actions to enable funding (NL, PT, and SI). A discussion in one case study interview focused on where government should stay in control, where can the private sector take control, and who should own the digital infrastructure (NL).

One of the main barriers to implementing Smart Spaces is economic/financial. Gartner predicts[52] that, by 2024, 70% of smart city programs that do not adopt and govern a multi-source funding model will fail to scale. According to Gartner research[53], governments must consider where different goals and objectives fit on the spectrum from command and control to influence to manage risks better, identify possible funding opportunities and help decide which management approaches will drive initiatives forward. For example, Smart City use cases of public safety management or street maintenance would be under the full command and control governance and funded by the public sector. Street lighting or parking meter management would be in the public-private-partnership governance area, where the government keeps a level of control, but the partner has some level of influence. Use cases relating to fully private funded initiatives, such as ride-sharing – would be under a governance strongly influenced by the private sector.

However, regardless of where a project falls on the spectrum, the public sector needs to promote accountability by establishing key performance indicators and publishing outcomes publicly for both services delivered by the government and those delivered by partners. This provides a common ground for evaluating projects owned by different stakeholders across a Smart Space, allowing these various projects to be managed and monitored according to public values, as recommended in one of the case studies (NL).

This model of varied governance approaches is also valid for managing the data - including location data - in a Smart Space. For example, cadastre data is in the sphere of command and control governance, whereas data from the position of cars are in the hands of the private sector, and any initiative funded on a public/private partnership would be in the middle of the spectrum and would exploit data that can be co-managed, such as relating to the positioning of street lighting or parking meters.

We summarise these findings in Table 17.

Table 17. Case studies: funding and financing of Smart Spaces

Case studies: funding and financing of Smart Spaces		
Barrier	Enabler	Action
Lack of funding	(EE,FI; PT, NL) Funding	(EE,FI; PT, NL) Procurement and research funding
	(NL, PT, SI) Public-private partnerships	(NL, SI, PT) Partner with the private sector to accelerate technology deployment; (NL) Adapt governance to use cases, monitor public value outcomes.

[51] In Slovenia, there are also several public tenders for municipalities in Minimum Viable Product (MVP) stages funded by the public sector, but this was not the approach used in the case study.

[52] Gartner (2020d), Smart City Funding Models: It's Time to Be Creative, ID: G00380634)

[53] idem

4.2 Trusting and valuing the investment

A second barrier to the implementation of Smart Spaces is the lack of trust in investing in technology, the lack of understanding of the use cases and technology, the fact that the value of a Smart Space is not perceived (NL, PT, and SI). According to Gartner research[54], two major considerations associated with any large technology investment are the irrecoverable cost of the project and the uncertainty about the value returned. Usually, the initiatives with the most measurable return on investment (ROI) receive the funding rather than those with the greatest potential returns. From the case studies, a **first** type of enabler relates to **proofs of concept and minimal viable products** (EE, FI; NL, SI), which can provide a means to understand and showcase user value quickly. A proof of concept can be developed generically to be reused for different use cases (EE, FI). A minimum viable product (MVP) is the release of a new product used to validate customer needs and includes only the minimum capabilities required to be a viable customer solution to reduce development time and effort. These can be procured/financed by the public sector and implemented through public/private partnerships (SI) or by a private company owned by the public sector (EE, FI). This approach also caters to the need for the public sector to invest in new technology, although it does not have the innovation capacity due to slow procurement cycles, lack of skills etc.

Understanding the profitability of an innovation investment can be done by developing cost/benefit analysis and **business cases** (NL), the **second** set of enablers. According to a case study (NL), one of the reasons that the public sector does not take risks in investing in new technology, compared to the private sector, is that the notion of ROI for digital investments is measured on a shorter time span than in the private sector (3 years versus 10 years). The private sector can accelerate technology deployment in a public-private partnership model where sharing the risks implies also sharing the rewards. According to Gartner research, there are several commercial models for these public-private partnerships, including management contracts, operating contracts, long-term leasing and build – operate - transfer[55]. Public-private partnerships provide a means to share benefits and risks between government entities and the private sector. To create win-win situations, all parties involved in public-private partnerships need to be clear about their tolerance for risk and expectations of benefit. Public-private partnerships can take the form of cost-sharing agreements, profit-sharing agreements and risk-sharing agreements.

One of the case studies proved to be a challenge to develop a business case for an infrastructure such as an urban platform, which is a “cross-use case” and does not identify a specific innovation-related use case value. To justify investments, the public sector needed the means to evaluate investments in such a critical infrastructure (NL). An approach to funding infrastructure innovation was to leverage maintenance budgets (NL) which paid the expert's salary in charge of upgrading the location information of the city using new technology (sensors, digital twins, etc.).

A **third** enabler is about building **trust** among the involved partners. This can be done through a triple helix collaboration (NL) in the case studies. Triple Helix is a concept of close cooperation between governments, the private sector and universities. This cooperation aims to be profitable in enhancing innovation and economic growth in a region.

We summarise the findings from the case studies in Table 18.

[54] Gartner (2020e), Market Trends: 3 Trends Impacting the Measurement of Smart City Technologies Benefits, ID: G00716790

[55] The private operator designs, finances and builds infrastructure; while the public sector assumes formal ownership of the system, the operator runs the project long enough to reclaim the investment and make a profit.

Table 18. Case studies: trusting and valuing the investment

Case studies: trusting and valuing the investment		
Barrier	Enabler	Action
Lack of trust in investing in technology, lack of understanding of the use cases and technology, the fact that the value of a Smart Space is not perceived	(EE, FI; SI) Proofs of concept and minimal viable products to understand and showcase user value	(EE,FI; SI) Procure POCs and MVPs before procuring the full solution.
	(NL; PT) Cost/benefit analysis, business cases with return on investment from the private sector	(NL; PT; SI) Partner with private sector to accelerate technology deployment.
	(NL) Build trust among stakeholders	(NL) Triple Helix Collaboration[56].

4.3 Stimulating availability of (location) data

A third barrier to implementing Smart Spaces is the **lack of data** and the difficulty in accessing data.

From the case studies, a first set of enablers clearly identified in all the case studies are **data platforms and marketplaces**. (EE, FI) The cross-border FinEst Twins pilot uses data readily available on the open data marketplaces (e.g. cadastre data and data from maritime traffic available as open data).

Procuring data platforms is a common public sector action across the case studies (NL, PT, and SI). Because of the siloed approach to data ownership, implementing a data platform makes data available across organisations (NL). Various stakeholder groups (for example, municipality departments or developers on an urban platform) should have similar access to data and levels of service (in line with security and privacy requirements) (SI).

Complementarily, another action identified in the case studies (PT) is launching procurement actions for the acquisition and/or digitisation of data sets and ensuring that open standards are used. The case study participants also recommend engaging citizen communities in data sharing.

A second enabler is (NL) the **availability of sensors** for data capture. The public sector can procure and ensure common data capturing devices for multiple systems, supporting common approaches for measuring, for example, air quality. This action promotes "single truth" approaches, providing similar/comparable data points by encouraging synergies in hardware for sensors capturing data, such as poles in cities capturing light, air, or video signals.

A third enabler is having the contractual obligation to deliver data (NL) alongside the solution to ensure data availability. Such an agreement would cover a pro-active service from the contractor/ company implementing the solution to send the data automatically to the municipality.

Again, we summarise these findings in the table below (Table 19).

[56] Triple Helix is a concept of close cooperation between governments, private sector and research institutions (often universities). This cooperation aims to be profitable in enhancing innovation and economic growth in a region.

Table 19. Case studies: stimulating availability of location data: barriers, enablers and actions

Case studies: stimulating availability of location data		
Barrier	Enabler	Action
Lack of data	(NL; PT; SI) Data platforms and marketplaces	(PT) Procuring data platforms; (PT) Procuring data sets; (PT) Engage citizen community with data sharing.
	(NL) Availability of sensors for data capture	(NL) Procure common data capturing devices for multiple systems.
	(NL) Obligation to deliver data in open standards, in addition to the solution	(NL) Ensure agreement is contractually in place for automatic sharing of data.

4.4 Ensuring interoperability

The fourth barrier to the implementation of Smart Spaces is the lack of interoperability that lowers the ease of integration between various systems, with connectedness being a key aspect of a Smart Space. According to Gartner research[57], in 2020, to address integration requirements, organisations spent approximately $22 billion on integration technologies.

From the case studies, the most cited enabler is the usage of **open standards[58]**, and related public-sector actions are about encouraging or enforcing their usage (EE, FI; NL, PT, SI). For example, the Minimal Interoperability Mechanisms[59] are currently used in most of the solutions described in the case studies, where the public sector requests them.

The second enabler cited is the **consolidation of standards** amongst various industries; in the area of Smart Spaces, and more specifically, Smart Cities, the Geospatial and Building Information Modelling worlds are still separate, and there is a need for energy, building and ICT sector alliances. The public sector could support this area of standards development.

We summarise these findings in Table 20.

Table 20. Case studies: ensuring interoperability

Case studies: ensuring interoperability		
Barrier	Enabler	Action
Lack of interoperability	(EE, FI; NL; PT) Open standards	(NL; PT; SI) Encourage/ enforce usage of open standards, including usage of Open API for integration.
	(NL) Consolidation of standards amongst various industries	(NL) Support standards development.

57 Gartner (2021a), How to Justify Strategic Investments in Integration Technology, ID: G00385596)

58 From the (EE, FI) case, we got relevant input: No need to create one standard covering everything, we can convert data from one standard to another, with the calibration of a connector. If the data standard is closed, there is an extra step to contact the vendor, but this can be done.

59 Minimal Interoperability Mechanisms (MIMs), see also footnote 43.

The public sector already takes part in standardisation processes, and to ensure consistent applications, this would need to be organised at supra-national levels as it is done for the Context Broker and the MIMs.

According to Gartner research[60], by 2023, 50% of government organisations will establish formal accountability structures for data sharing, including standards for data structure, quality and timeliness. Perceived barriers to data sharing have been shown to be surmountable: whereas data sharing was a known opportunity before COVID-19, it is now clear to policymakers how important it is to leverage timely and accurate data across multiple fronts.

Table 21 provides the overview of the standards used in the four case studies. This interoperability landscape classifies the standards by types – or "worlds" - such as Artificial Intelligence, Smart City and Digital Twins, or the Internet of Things. This classification aims to understand how "different worlds" are covered and if there is some merging of different "worlds" with a standard used in several different "worlds".

Table 21. Benchmarking the interoperability landscape from the case studies

Interoperability landscape	EE, FI	NL	PT	SI
Artificial Intelligence	There is a need for data quality standards[61]		Standard needed (processing and publishing steps)	
Digital Twins	City GML and underlying ISO standards	CityGML MIMs: Smart data models, Context Information, Data Marketplace (Ecosystem Transaction Management)	SAREF4City CityGML Open Agile Smart Cities MIMs: Context information NGSI/NGSI-LD, Smart Data models, Data Marketplace	
Internet of Things		Sensor of Things API MIM Smart data models GeoTIFF, GeoJSON	NGSI / NGSI-LD oneM2M MIM Smart Data Models SAREF SAREF4City GeoJSON GeoTIFF	MQTT AMQP REST endpoints NGSI ready REST, Web Socket Ready for: NGSI v2 endpoints
Event Stream Processing	For observation and measurements: ISO19156	MQTT	NGSI/NGSI-LD oneM2M MQTT LwM2M SiRi / NeTEX NGSI	MQTT AMQP Ready for: NGSI v2 endpoints
Building Information Modelling (BIM)		BIM IFC	CoBIe	
Geospatial standards		WFS, WMS, WMTS		
Open Data Standards	Implementation of ISO19141 Schema for moving features	OpenAPI INSPIRE	Open Data Standards Swagger/ Open API CKAN	INSPIRE OGC standards

The interoperability landscape shows a high level of comprehensiveness. The case study interviews identified only a few areas where standards were missing. In the Artificial Intelligence area, there is a need for data quality standards (SI); when applying AI algorithms, the data needs to be verified afterwards to check if the outcome is still at the level of quality expected (for example, verifying changes to City GML). An example of a

[60] Gartner (2021), Top Trends in Government for 2021: Data Sharing as a Program, ID: G00746196

[61] When applying AI algorithms, we need to verify the data afterwards (for example changes to City GML). An example is ISO19157: Geographic information — Data quality.

standard that can be used is ISO19157 Geographic information data quality, but the case study pilot has not yet implemented that check. Another area where standards are missing is in the way to structure information in a harmonised way across cities. An initiative in this domain is the City Data Standard - Mobility (CDS-M), an open data standard for data exchange between cities and shared mobility operators developed by the G-5 and the Ministry of Infrastructure and Water in the Netherlands[62].

The MIMs are used extensively in the approaches described in the case studies. As they are based on an inclusive list of baselines and references (see Table 22), MIMs[63] consider 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 technical architecture use the same interoperability mechanisms. The MIMs are developed in the OASC ecosystem, and some members of this ecosystem, namely Digital Rotterdam (NL), are taking the lead in further developing MIMs to align with their specific needs, for example, MIMs relating to Privacy & Security Management, or Data Storage. This demonstrates that the approach on interoperability used by the MIMs is identified as a good practice, and although a MIM is more efficient if there is a large consensus/user base, stakeholders can take initiatives, creating a grass-roots approach awareness and solutions of interoperability issues.

Exlicitly related to location, the newly established MIM 7 (Places) specifies approaches for sharing spatial (and spatio-temporal) data, make them interoperable with, within, and between systems and territories[64]. It is to a ery large extent based on international standards, specifically the ones developed by the Open Geospatial Consortium, and draws on the lessons learned from the implementation of INSPIRE.

Table 22. MIMs relevant for the selected case studies - descriptions and baselines

MIM Name	Interoperability point	Description	Standards and [baseline]
OASC Context Information Management MIM	Context Information Management API	This API allows access to real-time context information from different cities.	ETSI NGSI-LD API , OMA NGSI, ITU- T SG20/FG-DPM [FIWARE NGSI]
OASC Data Models MIM	Shared Data Models	Guidelines and catalogue of common data models in different sectors to enable interoperability for applications and systems among different cities.	[SAREF, FIWARE, GSMA, schema.org, SynchroniCity RZ + partner data models]
OASC Ecosystem Transactions Management MIM	Marketplace API	The Marketplace API exposes functionalities such as catalogue management, ordering management, revenue management, Service Level Agreements (SLA), license management, etc. Complemented by marketplaces for hardware and services.	[TM Forum Business Ecosystem API, FIWARE Business Ecosystem and Marketplace Enabler API, SynchroniCity API]
OASC Places MIM	Sharing spatial and spatio-temporal data	Specifies how to share spatial (and spatio-temporal) data, make them interoperable with, within, and between systems and territories.	CityGML, CityJSON, GeoJSON, OGC API-Features, SensorThings API, ISO19139

This section on enablers to interoperability focused on standards and other common agreements used to ease data integration as a partial outcome of the benchmarking exercise aiming to understand how data, especially

[62] POLIS (2021), Dutch cities develop new mobility data standard, https://www.polisnetwork.eu/news/dutch-cities-develop-new-mobility-data-standard/

[63] Taken from OASC (2019), Minimal Interoperability Mechanisms (MIMs), https://oascities.org/wp-content/uploads/2019/06/OASC-MIMs.pdf

[64] For detailed information on MIM 7 (Places), see https://mims.oascities.org/interaction/oasc-mim7-places

location data, is exchanged within the Smart Space. We can conclude that technical integration and access mechanisms are important, as are collaboration/interoperability agreements, service levels, simple and common licensing, standards built into legislation and other interoperability enablers are provided in the European Interoperability Framework catalogue.

4.5 Facilitating uptake

This section analyses the barriers relating to the uptake of a Smart Space, namely the lack of political drive, the lack of trust and the lack of skills, and legal aspects relating to data privacy.

The first barrier - **lack of political drive** - is identified in several of the case studies, but proposed enablers have proven to be efficient: raising awareness, showcasing value proposition (PT), educating on Smart Spaces and their benefits (NL), or disseminating through pilots (EE, FI). These public sector actions aiming to improve understanding of the value of Smart Spaces amongst decision-makers are important, with evidence provided "from the field" through piloting and demonstrating of benefits. Enablers relating to change management, such as change culture and making middle management accountable for change (NL), are also key in ensuring uptake of the Smart Spaces.

The second barrier to uptake is legal and relates to data privacy (NL), with **legal compliance** (NL, PT, SI) as a straightforward enabler. Compliance with GDPR and other privacy regulations must be requested in procurement and monitored for compliance. Ensuring the management of the complete data life cycle (NL) is an enabler, complementarily to the regulatory compliance. With the public sector implementing (or procuring) a data life cycle management strategy, it can ensure that data is destroyed when needed, enforce the right to be forgotten, etc.

Lack of trust in security is a third barrier, and case study feedback identifies (NL) designing of IT systems to increase security as a good practice, with the public sector introducing various levels of data access to the Smart Space to avoid security and privacy issues with potentially sensitive data. Experimenting with *Proofs of concept* also helps understand and address the potential lack of trust. Gartner research[65] predicts that, through 2023, organisations that can instil digital trust will be able to participate in 50% more ecosystems, expanding revenue generation opportunities.

We have not identified specific technologies relating to trust in the case studies, except for access management. Gartner recommends the adoption of digital trust technologies such as blockchain smart contracts, which enable a trusted data collection method while also enabling the efficient transfer and sharing of any asset of monetary or nonmonetary value. For example, you can integrate IoT systems with blockchain distributed ledger technology to create a shared, single version of the truth and increase trust in the data collected by the Internet of Things (IoT). They will also help to improve situation awareness across multiparty ecosystems.

The **lack of skills** is the fourth barrier, with (NL) Access to technology skills for implementing the Smart Space, with (NL, SI) training and technology skills acquisition being a first enabler, followed by (SI) Public-private partnerships as a second enabler. The public sector can partner with the private sector (NL, SI) and can outsource some implementations to universities and research institutes (NL). One of the cases (EE, FI) mentioned that the availability of documentation on open standards lowers the need for specific skills such as geospatial experts, with more generalist experts being able to understand the requirements.

We summarise these findings in Table 23.

[65] Gartner (2020f), Why Data Sharing Is Important: Introducing Gartner's 'Must Share' Model, ID: G00727589

Table 23. Case studies: building uptake

Case studies: building uptake		
Barrier	Enabler (incl. case study example)	Action (incl. case study example)
Lack of political drive	(NL) Education on Smart Spaces and its benefits (EE, FI) Piloting dissemination (NL) Support from the field to explain benefits of change to middle and top management	(NL) Improve understanding of the value of Smart Spaces amongst decision-makers; (NL, PT) Raise awareness, showcase value proposition.
	(NL) Change culture and middle management accountability	(NL) Top-down support needed to enforce change in middle management.
Legal aspects relating to data privacy	(NL) Legal compliance	(NL) Compliance with GDPR and other regulations.
	(NL) Ensure data life cycle management	(NL) Implement a data life cycle management strategy (destroy the data, enforce the right to be forgotten).
Lack of trust in security	(NL) Modular design of IT systems to increase security	(NL) introduce various levels of data access to avoid security and privacy issues with potentially sensitive data.
Lack of skills	(NL) Access to technology skills for implementing the Smart Space, through (SI) Training and Skills Acquisition (SI) Public-private partnerships (EE, FI) availability of documentation on open standards lowers the need for specific skills	(NL) Ensure training; (NL) Outsourcing to university and research institutes; (NL, SI) Partner with the private sector, public-private partnerships.

5 Conclusions and recommendations

This report focused on three areas of work. The first one detailed the approach and outcome of creating a benchmarking framework analysing location intelligence and the role of the public sector in Smart Spaces. The second one exemplified the framework's usage with four case studies and provided an analysis of the content of the case studies (benchmarking the roles of the public sector and benchmarking location intelligence and its contribution to public value). The third one – also building on the case study content – benchmarked the enablers and barriers of a Smart Space in the case studies and proposed five areas where the public sector can act to lower the barriers of implementing Smart Spaces.

In our conclusions, we address the outcomes of these areas of study by setting the key takeaways from benchmarking the roles of the public sector and location intelligence in a wider context and suggesting future research. As this study is developed in the scope of the ELISE Action, we then close this report with further recommendations for the public and the private sector actions regarding location data and interoperability.

5.1 Concluding remarks

5.1.1 Benchmarking the roles of the public sector

From the four cases that we examined, public sector roles as data provider and data consumer seem common across the value chain. However, the role of data broker appeared limited to providing access to the data at the exchange step. Other existing examples invalidate this restricted view. The public sector will typically act as a broker in the transport sector, integrating transport timetables and services from different public and private sector transport providers, and in the energy sector, running and regulating energy networks and markets, with information from different energy companies and operationally, for utilities, brokering asset maintenance activities[66]. European and national statistical agencies act as data brokers for large amounts of statistical data on many different topics, similarly INTERPOL on crime data, and various agencies involved in weather data sharing. The brokering activities are typically associated with coordination on and enforcement of standards (the cable information exchange portal (KLIP) uses data exchange mechanisms based on INSPIRE, with private sector companies committing to use these standards).

As for its role regarding standardisation activities and requesting, through procurement, the usage of standards, the public sector takes part in standardisation processes. Although this was not identified in the case studies' public sector organisations, it is worth mentioning that European mapping agencies collaborate through UN-GGIM Europe and EuroGeographics on standards for pan-European mapping.

5.1.2 Benchmarking location intelligence and its contribution to public value

The analysis from the case studies on location intelligence, the insight generated, its impact and its contribution to the **public value** in the Smart Spaces shows its role in Smart Spaces is key. In this work, we considered public value in the form of economic and financial value, citizen value and user attractiveness, administrative value and effectiveness, and democratic value and trust. From the cases that we selected for this work, we can conclude that the public value gained through the application of location intelligence in Smart Spaces is overall perceived as a medium to high, meaning that the added value is clearly recognised in all four case studies, with a predicted increase over time. The value for both citizens and public administration is considered relatively higher than financial gains. The democratic value appears most diverging between the different use cases examined.

Notably, while this work was carried out, there are other ongoing discussions within the ELISE Action to categorise and assess the public value of location-enabled public services[67]. Initial findings suggest, as an alternative, to classify public value in the operational, political and social categories[68]. Whereas discussions are still ongoing, future versions of the Benchmarking Framework presented here would benefit from an alignment to the final results of this parallel investigations.

[66] See the example of the pipeline and cable information exchange portal (KLIP) as described in https://joinup.ec.europa.eu/collection/elise-european-location-interoperability-solutions-e-government/document/report-location-intelligence-benchmarking-study

[67] See Joinup page on Innovative use of location data and technology to improve public services, https://joinup.ec.europa.eu/collection/elise-european-location-interoperability-solutions-e-government/innovative-use-location-data-and-technology-improve-public-services

[68] Barker L., Claps M., Stevens R., Crompvoets J., Nasi G. and Vandenbroucke D. (2020), Leveraging the Power of Location Information and Technologies to Improve Public Services at the Local Level - State of the Art Report, Schade S. (ed.), Publications Office of the European Union, Luxembourg, doi:10.2760/158709, https://publications.jrc.ec.europa.eu/repository/handle/JRC126562

Considering the delivery of public value, we should also consider the **evolution of Smart Spaces** and keep track of the importance of location intelligence within these different spaces. For example, the impact of the recent pandemic on the evolution of Smart Buildings is important. According to Gartner research, the requirement to make estates safe for occupancy and compliant with newly introduced COVID-19 regulations created a wave of new market interest in the smart buildings segment. Previously, the primary customer-driven adoption and perceived value were on energy-saving and efficiency improvement. The pandemic created a new driver firmly focused on people-centric safety and compliance, requiring strong location intelligence-related capabilities. Another example is the trend of the expansion of Smart Spaces across territorial aspects. The FinEst case study provides a glimpse of how this can be operationalised between different cities, but this interconnectedness between Smart Spaces will be highly relevant in the future as the long-term vision of the European Commission on rural areas[69] provides a first example.

According to Gartner research[70], in the ultimate manifestation of a Smart Space in the intelligent environment phase, there will be digital twin models of people, processes and things across a city. Event-driven structures will replace predefined hard-coded integration points. Virtual assistants and independent agents will monitor and coordinate activities across multiple systems inside organisations or government entities and across multiple entities. It will be possible to add new capabilities to existing environments without upgrading the entire infrastructure. Open data exchanges will reduce friction between different players in the data ecosystem and the information systems.

5.1.3 Development and future usage of the benchmarking framework

We needed a means to develop a deeper understanding of the challenges that Smart Spaces are facing in their development and the possible solutions that location intelligence might provide. Within the context of the ELISE Action, there was also a particular opportunity to identify areas where the public sector can help address these challenges.

The aim of developing this benchmarking framework was to obtain a useful analysis tool that can provide a clear “picture” of a Smart Space, identifying barriers, for example, in the interoperability of (location) data and technology, anticipating emerging needs, and the derived recommendations for improving the status quo – especially for required actions of the public sector.

To do this, the Framework benchmarks the Smart Space along four dimensions (see also Figure 3), structuring the collection of data to provide insight on the role of Location Intelligence in Smart Spaces and the role of the public sector. First, it allows understanding how, in a Smart Space, data is used to create public value using location intelligence. The second and third dimensions analyse in detail location data and intelligence and how it is exchanged, along the data value chain, the existing barriers and enablers, and the role of the public sector. The fourth dimension analyses the overall Smart Space by looking at its components and by assessing its maturity level.

The Framework was tested and developed with four case studies. Although all case studies related to smart Cities – with one covering a Smart Space *between* two cities – this Framework is applicable at the generic level of Smart Spaces, i.e. is to a large degree independent of the nature of the particular kind of Smart Space (smart city, smart village, smart building, etc.). The scope of the Smart Space targeted by the Framework is not limited by assumption.

The Framework dimensions and the related template extracting the relevant information from the distinct case studies were developed bearing in mind the Framework's usability – its ease of use in terms of size and length of questions to reply to. Based on the template's testing with several case studies, we enhanced it to make it more self-explanatory. However, collecting the feedback still needs to be done in collaboration with a person who knows the framework and can ensure the completeness and accuracy of the data collected.

The benefits of such a detailed and comprehensive framework reside in the knowledge sharing aspect. Ultimately, this Framework and its collection of in-depth case studies, such as those in the annex of this report, can provide a practical guidance Framework for developing a Smart Space, leveraging location intelligence, and where to focus related policy and investments. Another benefit of the current version of the Framework is to provide a structured analysis approach allowing easy comparisons between different Smart Spaces.

[69] Priorities of the European Commission 2019-2024, https://ec.europa.eu/info/strategy/priorities-2019-2024/new-push-european-democracy/long-term-vision-rural-areas_en

[70] Gartner (2019a), see also footnote 1.

In addition, we would also see benefit from lighter versions of the Framework, which can be explored as further research in this area, and which would provide a "fast benchmark tool" in focused areas, such as interoperability landscapes or the roles of the public sector. With a targeted focus, these "self-assessment" benchmark frameworks can be deployed over a larger number of cases and provide a more representative view of the Smart Space landscape in these areas. A "campaign" of light benchmarks can quickly probe areas – for example, inviting the demand side (i.e., the private sector) to provide approaches to their interoperability landscapes and thoughts on areas where initiatives are lacking. This could help policymakers understand the impact of their interoperability strategies. A "light" benchmark carried out at a large rate on the role of the public sector in Smart Spaces would create a comprehensive view of the potential impact of public sector actions in these Smart Spaces by scanning a wider number of cases. This information would help target policy initiatives to the high priority areas with the most impact. Such an approach might also contribute to monitoring the ongoing digital transformation in the public sector, for example, by establishing mechanisms to share the results of self-assessments with those authorities (at regional, national and EU-level) dealing with the relevant digital policies.

5.2 Recommendations

While we witness the market for Smart Spaces expanding, we lack a deeper understanding of its challenges. Within the context of ELISE Action, we see a particular opportunity to **identify areas where the public sector and the private sector can help address these challenges**.

In the table below, we expand the barriers of lack of data and lack of interoperability, and the related enablers and actions that we distilled from the four case studies (see also Section 4 and Tables 17 - 23). The barriers are complemented with current and possible initiatives that can further improve the current situation, taken by both the private and the public sectors. Notably, the analysis of the case studies did not reveal issues related to (data) licenses another related topic which was discovered in other analysis. For related recommendations, we recommend consulting complementary work[71].

Table 24. From barriers to recommendations for the public and the private sector

<table>
<tr><th>Barrier</th><th>Public sector actions, incl. policy</th><th>Private sector actions</th></tr>
<tr><td rowspan="2">Lack of data, incl. its discoverability and access</td><td>Champion data sharing policies: including the INSPIRE Directive, Open Data Directive, European Strategy for Data, the (upcoming) Data Governance Act, the (proposed) Data Act, etc.
Drive location intelligence initiatives
Procure data sets, clarify ownership of data
Procure common data capturing devices for multiple systems</td><td>Contribute to develop a Common European Data Space, and applications building on top of it
Promote a culture of data sharing</td></tr>
<tr><td colspan="2">Develop Public-Private Partnerships: Common data platforms and marketplaces such as Copernicus with Data and Information Access Services (DIAS[72])
Promote common initiatives between cities (Living in EU[73])
Consider the billions of IoT devices as a shared infrastructure and ensure the monitoring of their quality and maintenance under common programmes</td></tr>
<tr><td>Lack of interoperability</td><td>Champion interoperability-related policies: EU Standardisation rolling plan[74], European</td><td>Innovate integration mechanisms, technology and tools</td></tr>
</table>

[71] See, for example, Martin, S., Gautier, P., Turki, S. and Kotsev, A. (2021), Establishment of Sustainable Data Ecosystems: Recommendations for the evolution of spatial data infrastructures, EUR 30626 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-31385-4, doi:10.2760/04462, JRC124148, https://publications.jrc.ec.europa.eu/repository/handle/JRC124148

[72] Copernicus Data and Information Access Services (DIAS), https://www.copernicus.eu/en/access-data/dias

[73] Web presence of the LivingIn.EU initiative, https://living-in.eu/

[74] EU Rolling Plan for ICT Standardisation, https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/rolling-plan-2020

Barrier	Public sector actions, incl. policy	Private sector actions
	Interoperability Framework, Location Interoperability Framework, (upcoming) Interoperability Policy Benefit from DIGITAL (incl. Interoperable Europe) for the reuse of existing solutions, including open-source ones[75] Encourage/ enforce usage of open standards, including usage of Open APIs for integration	
	Participate in common standardisation activities	

Based on these key recommendations for action, we substantiate some of the points in the table. We highlight their importance by providing additional information which sets them in a wider context.

The existing policies cited in the table contribute to countering the sheer lack of data, but also issues realted to access, discovery and interoperability of existing data sets. The importance of location data and its contribution to public value through location intelligence was put forward in the report, and it will continue to grow. It has been estimated[76] that approximately 80% of the informational needs of a local government policymaker is related to a geographical location. Gartner[77] predicts that by 2023, 20% of Geographic Information System (GIS) departments will become the office of the chief data officer due to the growing significance of geospatial data in government. The public sector should drive location intelligence initiatives. The public sector can drive the production of data by procuring the data sets and procuring systems that deliver data, as it is usually done. The private sector has a role in building the Data Spaces and sharing data. Common initiatives between public sector organisations can also support sharing data and re-use of solutions – such as Living in EU does at the city level. The study's findings show that public-private partnerships are important as they drive innovation, for example, by developing common data marketplaces and platforms; within this context, the public sector should understand and clarify ownership of data. Last, but not least, also citizens are actors in data ecosystems and they should have a say when it comes to the access and use of data concerning them[78].

Also in the future, with the production of data continuing to grow exponentially, policymakers will remain pressured by the need to address the quality of data generated – notably by the billions of IoT devices - to ensure that it can achieve high benefits for the particular end-user, but also for society as whole. Questions relating to how these devices can work together are key and the case studies developed in this report highlight means of doing so and the related challenges. As suggested in a case study, procurement of common data capturing devices for multiple systems is a possible first step towards some control on the way data is generated, its quality, and its consistency across various domains (such as air quality or noise). However, it has to be noted that also this approach has its limits, because the IoT is simply too fragmented and versatile. Another solution would be the reinforcement of the European stance in standardisation, as recently discussed in the context of the European Standardisation Strategy[79].

Monitoring, measuring and perhaps mandating interoperability aspects will actucally be one of the streams to build on, easing integration between systems. The lack of interoperability is seen as a second key barrier. As highlighted in the table, interoperability policies exist. While they are being implemented and their impact is illustrated in the case studies, Gartner[80] still expects an increase of integration efforts and expenditure to approximately $36 billion in 2025.

Gartner research shows that these investments in integration and API capabilities have enabled organisations to experience business value in four areas:

- Build competitive advantage by creatively assembling custom and standard systems,
- Enable business agility and change by adding innovation to legacy processes,

[75] EU Open Source Observatory (OSOR), https://joinup.ec.europa.eu/collection/open-source-observatory-osor/news/study-open-source-policies
[76] See discussion of this classic statement, https://www.gislounge.com/80-percent-data-is-geographic/
[77] Gartner (2021c), 3 Actions to Drive Digital Government Innovation Through Your Geospatial Program, ID: G00746614
[78] For inspiration and reference, see https://mydata.org/guiding-principles/
[79] See, for example, the recent consultation on the European standardisation system, https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13099-Standardisation-strategy_en
[80] Gartner (2021a), see also footnote 57.

- Provide insights and situation awareness by identifying critical events in a timely manner,
- Reduce costs and improve efficiency by streamlining processes.

This implies that there is an opportunity for innovating in the area of integration, such as the API approach. Besides, for new systems developed in a strong interoperability setting, integration costs will be lower, meaning that the impact of an interoperability regulation would reach both public and business value.

The recently launched launched Digital Europe Programme (DIGITAL)[81], including its Interoperable Europe initiative[82], provides plenty of opportunities to take the required actions, share the experiences, and adopt new interoperable solutions for the benefit of all. The programme will be instrumental for a rapid operationalisation of the legal provisions.

[81] See the official web page of the Digital Europe Programme, https://digital-strategy.ec.europa.eu/en/activities/digital-programme

[82] See the official web page of Interoperable Europe, https://joinup.ec.europa.eu/collection/interoperable-europe/interoperable-europe

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List of definitions

*A **data ecosystem*** is defined as a setup, where a number of actors interact with each other and their environment for a specific purpose, generating value from the network by producing, exchanging and consuming data in a collectively governed and operated way.[83]

A ***data space*** refers to a pool of data, associated tools and infrastructure necessary to use and exchange data, as well as appropriate governance mechanisms serving data needs in a particular policy area (e.g. health, mobility, environment, smart communities) and having a systemic impact on the entire ecosystem[84].

The ***Internet of Things (IoT)*** is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.[85]

Location interoperability is defined as the ability of organisations, systems and devices to exchange and make use of location data with a coherent and consistent approach.[86]

Location intelligence is defined as the process of deriving meaningful insight from geospatial data relationships – people, places or things.[87]

Minimal Interoperability Mechanisms (MIMs) are the minimal common technical ground needed in a global market for IoT-enabled services for cities and communities.[88]

A ***minimum viable product* (MVP)** is the release of a new product (or a major new feature) that is used to validate customer needs and demands prior to developing a more fully-featured product. To reduce development time and effort, an MVP includes only the minimum capabilities required to be a viable customer solution.[89]

Mobility-as-a-Service (MaaS) is an emerging type of service that, through a joint digital channel, enables users to plan, book, and pay for multiple types of mobility service.[90]

A ***proof of concept* (POC)** is a demonstration of a product, service or solution in a sales context. A POC should demonstrate that the product or concept will fulfil customer requirements while also providing a compelling business case for adoption.[91]

A ***Smart Space*** is defined as a combination of physical and digital environments in which people and technology-enabled systems interact in dynamic, inter-connected and intelligent ecosystems.[92]

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83 EULF Blueprint, see also footnote 9.
84 A European strategy for data, see also footnote 12.
85 Gartner glossary on Information Technology, https://www.gartner.com/en/information-technology/glossary/internet-of-things
86 EULF Blueprint, see also footnote 9.
87 Gartner (2020a), see also footnote 3.
88 OASC, https://oascities.org/minimal-interoperability-mechanisms/
89 Gartner glossary on Marketing, https://www.gartner.com/en/marketing/glossary/minimum-viable-product-mvp-
90 Mladenović (2021), see also footnote 41.
91 Gartner glossary on Sales, https://www.gartner.com/en/sales/glossary/proof-of-concept-poc-
92 Gartner research (2019a), see also footnote 1.

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Annexes with details about the case studies

Below we present the details for each of the four selected case studies, following the template developed in Section 2.4.

Annex 1. FinEst Twins cross border feature (EE, FI)

FinEst Twins cross border feature (EE, FI)			
Name FINEST Twins: Crossborder Features	URL https://www.finesttwins.eu		
Lead Organisation Name Forum Virium Helsinki Oy	Lead Organisation Category Non-profit company owned by the city of Helsinki		
Description The project is a use case on the Urban Open Platform work package of the FinEst Twins project. The goal of the project is to provide a proof-of-concept implementation of a) cross-border geospatial models and b) implementation of the OGC Moving Features concept or a similar mechanism in the domain of Smart Mobility			
Administrative level Sub-national, City	Geographic coverage Finland, Estonia	Start Date 1.12.2019	Still Active Yes

Dimension 1: Location intelligence contribution to public value in Smart Spaces		
Example Use Case	**Location intelligence type**	**Type of decision making and impact**
FinEst Moving Features – cross-border use case for maritime information	(1) **descriptive analytics** that uses data to describe, summarise and visualise information, as well as mining and aggregating current and historical data to gain insight (2) **predictive analytics** that uses machine learning with data to make predictions and uses statistical and probabilistic techniques to predict future trends and outcomes	**Type of decision making:** - End-user **Impact:** - Short term

Public Value of the use case			
Economic and financial value (Inc. Efficiency)	**Citizen value and user attractiveness** (incl. Social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. Transparency)
- Medium	- High	- Medium	- High

Dimension 2: Role of Location Data and Public Sector actions			
Data Value Chain Steps			
Generation	**Collection**	**Processing**	**Exchange**
Data acquisition Information is captured in a digital format from devices	Data organisation: collection and validation Collection and consolidation of data from multiple sources. Comprises checking of the data accuracy before integration into a valid dataset.	Data processing and analysis Processing data to generate insight using identification of patterns in the data, including descriptive, predictive and prescriptive analytics.	Data sharing and publishing Data is shared and published (through APIs, data portals, for example) to be used. At this stage, it can also be reused or repurposed.

Role of location data	**Generation**	**Collection**	**Processing**	**Exchange**
Location Data is the service: Location data or location intelligence algorithms are the main value-generating component of a service. Example: navigation service		X	X	
Location data sources used by the pilot: • CityGML city models from Helsinki and Tallinn • Maritime traffic API from Finish transportation authority Processing these data to merge them so that Maritime data is converted into the location of the feature				
Location Data adds intelligence Location data or location intelligence algorithms enrich the value generated by products or services. Example: location-based advertising. Location intelligence algorithms analyse location data to make the product or service offering more intelligent. Example: Shortest route calculation			X	X
The pilot is conceived to enable ETA in the future				
Location Data supports data validation activities: Location data is used to validate other sets of data. Example: Location data in lampposts validate earthquake information identified by other data				

Role of the public sector	**Data Value Chain**			
	Generation	**Collection**	**Processing**	**Exchange**
Data provider		X	X	
Collection: Public sector is providing City GML and cadastre data				

	Data Value Chain			
Processing: The vessel is generating the data (Automatic Identification System), provided by the maritime authority				
Data Consumer				
Only the private sector will probably use the data (in the form of a road planner)				
Data Broker				
This is a trend in the sector, MaaS (mobility as a service), but not yet implemented				
Data Owner		X		
Collection: cadastre data is open data owned by the public sector				
Supports or enforces standardisation	X			
Generation: the OGC Moving features SWG is leveraged here. Public sector is participating in the OGC SWG, especially the government of Japan. Using open standards is recommended in research projects funded by EU.				

Enablers and barriers of a Smart Space and location intelligence, and related public sector actions				
	Barriers	**Yes**	**Enablers**	**Public sector action**
Economic	Lack of funding, uncertainty relating to hidden costs		Financing/ Funding	Research funding (2-3 weeks of effort)
	Low demand: Lack of trust in the use cases and technology, value not perceived		Proof of concept/piloting development	POF on moving features, which can be reused in other use cases - genericity of use cases
Organisational	Lack of political drive	**Not a barrier in this case**	Piloting dissemination	Raise awareness, showcase value proposition
	Need for orchestration and maintenance of new and legacy technology across many manufacturers	**Not a barrier in this case**	Openness	Usage of open standard – ease of reuse of data from the API
	Lack of data Difficulty in accessing data	**Not a barrier in this case**	Usage of existing APIs (maritime)	Growing need for Mobility as a service in the future, market for this is at a very early stage, not yet seen if they can compete with open data market places
Legal	Data Privacy issues	**Not a barrier in this case**		Compliance with GDPR and other regulations
Technical	Lack of computation capacity	**Not a barrier in this case**		Public-private partnerships Procurement for IT computation

Enablers and barriers of a Smart Space and location intelligence, and related public sector actions				
	Lack of innovative technology (ex: real-time data sharing)		Company-owned by the city	*More competitive rates to hire, easier to participate in pilots*
	Lack of trust in investing in technology (ex: Cloud)	**Pilots and POCs help to understand the potential lack of trust**		
	Network un-reliability	**Not a barrier in this case**		
	Interoperability/ Standards Usage of older OT assets that lack integration, data acquisition and ingestion standards			Open standards No need to create one standard covering everything, converting data from one standard to another, calibration of a connector. If the standard is closed, this would require the additional step to agree with the industry partner to access the documentation of the standard.
	Lack of skills	**Not a barrier in this case**		Thorough documentation of the APIs, no need to have geospatial experts
	Lack of trust in security	**Not a barrier in this case**		

Dimension 3: Location data interoperability and exchange
Use case: The solution utilizes the static 3D city models of Helsinki and Tallinn, creates a Moving Feature object according to the OGC best practices and updates the location information using the public, open data API (https://www.digitraffic.fi/en/marine-traffic/). The data integration and processing capabilities are part of the Helsinki Urban Platform experimental platform, where the data processing is based on open-source Apache Camel and Apache Kafka products. Some geospatial data conversions are made using the FME Cloud data manipulation platform to merge the two city models.

Location data exchange capabilities

Integration styles	Managed file transfer	ETL (Extraction, Transformation and Loading)	Data virtualisation	Change data capture	Stream Processing	Event-driven architecture	Message-Driven Architecture	API mediation	Service-oriented architecture
(1) Location data set type and standards		MARITIME TRAFFIC API GEO-JASON CityGML semantic model							
(2) Tools		FME Cloud			Kafka will be used for observation (if needed)			TUIK for API management part of the urban platform	

Location Data – Tools and Standards

	Data Value Chain			
	Generation	Collection	Processing	Exchange
(1) Location Data Sources See above				
(2) Tools See above				
	Data Value Chain			

	Generation	Collection	Processing	Exchange
(3) Standards				
Artificial Intelligence			There is a need for data quality standard: when applying AI algorithms, need to verify the data afterwards (for example, changes to City GML) An example is ISO19157	
Smart City and Digital Twin		City GML and underlying ISO standards		
Internet of Things	The handling and processing of IoT Data is done in event stream processing			
Event Stream Processing			ISO19156 Observation and measurements (If Kafka is used)	
Building Information Modelling				
Open Data Standards				Implementation of ISO19141 Schema form moving features

Dimension 4: Smart Space maturity and components				
Smart Space Maturity Level				
Gartner research[93] sees four phases of Smart Spaces underscored by five dimensions.				
Stage	**Phase 1 Isolated Systems**	**Phase 2 Connected Systems**	**Phase 3 Coordinated Systems**	**Phase 4 Intelligent Environments**
Openness	none	Internal	External	**Fully**
Openness. Openness refers to the degree of accessibility to the elements in a Smart Space, including data. In an open model, systems can interact with each other with data exposed and accessible through standardised mechanisms. Trends in open data formats, identifiers and protocols, as well as the work of open-source communities, are driving this aspect of Smart Spaces.				
Connectedness	none	**Yes**	Yes	Yes
Connectedness refers to the depth, breadth and robustness of the connections between the elements in a Smart Space. Connectedness is closely linked to openness. As the mechanisms to access the attributes, data and functions of an application increase, so does the degree of openness. Increasing the granularity of the accessible attributes, data and functions also increases connectedness. Trends such as IoT, IoT platforms, digital twins, edge computing, APIs and API gateways, and mesh app and service architecture all contribute to greater connectedness in a Smart Space.				
Coordination	none	**Integration**	Coordination	Coordination
Coordination refers to the depth and strength of coordination between the elements in a Smart Space. Coordination is a more active aspect of Smart Spaces that builds on connectedness. While connectedness looks at the opportunity to connect various elements, coordination looks at the actual level of interaction and cooperation between the elements. For example, two applications operating in a Smart Space that shared login credentials would have a very low coordination score. However, if they also shared data and had tightly integrated process execution, they would have a much higher coordination score. Trends such as MASA, APIs and events also factor into coordination. Coordination in this context refers not only to technical coordination, but also to the coordination of people and processes based on the underlying technology.				
Intelligence	none	**none**	Semi-intelligent	Intelligent
Intelligence refers to the use of machine learning and other AI techniques to drive automation into the Smart Space and deliver services to augment the activities of people within it. Intelligence can manifest itself in the form of autonomous things or augmented intelligence, including augmented analytics. An important aspect is the use of AI to deliver intelligent multimodal and multidevice immersive experiences to enhance how users perceive and interact with the various elements in the Smart Space.				
Scope	Team	Department	One organisation	**Ecosystem**
Scope refers to the breadth of a Smart Space and its participants. A Smart Space with a very narrow scope might focus on a single team within a department of a large organization. A Smart Space with a broader scope might focus more across the organization but within a bounded problem space. A Smart Space with an even broader scope might include elements external to the organization with an ecosystem of participants. Openness, connectedness and coordination set the stage for increasing the scope of a Smart Space. Intelligence promotes simplified access and automated management as the scope of a Smart Space increases.				

[93] Gartner (2019b), see also footnote 23.

Smart Space Component Category	Component description
Data Sources	
Static data	Cadaster data
Dynamic data	Maritime traffic API
Location data	See above
Data capturing devices	None (part of this pilot)
Cloud	
Public	FME Cloud, Kafka in the cloud (if needed)
Private	
Analytics	
Location Intelligence	Not defined yet – Jupiter Notebook or “R” as microservice
Integration and interoperability	
API Gateway	
Context Broker	
ESB	
MIMs	
Platforms	
Digital Twin	
Urban Platform	Linkage to Helsinki and Tallinn urban platforms through Kafka and FME
other	Kubernetes
Formalised Ecosystems	
OASC	
FIWARE	
OGC	Participation in moving features SWG

Annex 2. The Digital City of Rotterdam (NL)

The Digital City of Rotterdam (NL)	
Name Rotterdam Digital City	URL https://www.rotterdam.nl/wonen-leven/digitaal/
Lead Organisation Name Gemeente Rotterdam	Lead Organisation Category Governmental

Description
The Municipality of Rotterdam is investigating the possibilities for the future city in the Digital City program. The core of this program is the development of a digital Open Urban Platform with a 3D Digital Twin of Rotterdam. Knowledge is now being gained through projects and pilots to further stimulate these developments.

Administrative level	Geographic coverage	Start Date	Still Active
Sub-national, City	The Netherlands	2017	Yes

Dimension 1: Location intelligence contribution to public value in Smart Spaces

Example Use Case	**Location intelligence type**	**Type of decision making and impact**
Spatial Planning 3D gaming	(1) **descriptive analytics** that uses data to describe, summarise and visualise information, as well as mining and aggregating current and historical data to gain insight (spatial analysis)	**Type of decision making:** - End-user - Strategic **Impact:** - Medium term

Public Value of the use case			
Economic and financial value (Inc. Efficiency)	**Citizen value and user attractiveness** (incl. Social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. Transparency)
- Medium	- High	- High	- High

Example Use Case	**Location intelligence type**	**Type of decision making and impact**
Integrated environmental permit	(1) **descriptive analytics** that uses data to describe, summarise and visualise information, as well as mining and aggregating current and historical data to gain insight (location analysis)	**Type of decision making:** - End-user **Impact:** - Medium term

Public Value of the use case			
Economic and financial value (Inc. Efficiency)	**Citizen value and user attractiveness** (incl. Social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. Transparency)

Example Use Case	Location intelligence type		Type of decision making and impact
- Medium	- High	- High	- Medium

Example Use Case	Location intelligence type	Type of decision making and impact
SAFE 3D Physical safety of people near and in buildings	(2) **predictive analytics** that uses machine learning with data to make predictions and uses statistical and probabilistic techniques to predict future trends and outcomes	**Type of decision making:** - End-user **Impact:** - Medium term

Public Value of the use case			
Economic and financial value (Inc. Efficiency)	**Citizen value and user attractiveness** (incl. Social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. Transparency)
- Medium	- High	- High	- Medium

Example Use Case	Location intelligence type	Type of decision making and impact
3D Building Information and AR	(1) **descriptive analytics** that uses data to describe, summarise and visualise information, as well as mining and aggregating current and historical data to gain insight (spatial analysis)	**Type of decision making:** - Strategic **Impact:** - Long term

Public Value of the use case			
Economic and financial value (Inc. Efficiency)	**Citizen value and user attractiveness** (incl. Social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. Transparency)
- Low	- High	- Medium	- High

Dimension 2: Role of Location Data and Public Sector actions

Selected use case name: ***all***

Data Value Chain Steps			
Generation	**Collection**	**Processing**	**Exchange**

Dimension 2: Role of Location Data and Public Sector actions			
Data acquisition Information is captured in a digital format from devices	Data organisation: collection and validation Collection and consolidation of data from multiple sources. Comprises checking of the data accuracy before integration into a valid dataset.	Data processing and analysis Processing data to generate insight using identification of patterns in the data, including descriptive, predictive and prescriptive analytics.	Data sharing and publishing Data is shared and published (through APIs, data portals, for example) to be used. At this stage, it can also be reused or repurposed.

	Data Value Chain			
Role of location data	Generation	Collection	Processing	Exchange
Location Data is the service: Location data or location intelligence algorithms are the main value-generating component of a service. Example: navigation service	X	X	X	X

Generation, Collection, Processing, Exchange: Location data is the teach step of the value chain. All data should have a location-based element, and in most cases, there is a location element in it, such as an address (typed). Not all data is geo-coded, but important generic registries are.

Location Data adds intelligence Location data or location intelligence algorithms enrich the value generated by products or services. Example: location-based advertising. Location intelligence algorithms are analysing location data to make the product or service offering more intelligent. Example: Shortest route calculation			X	

Processing: Location data is used to process information – where are the bins located for example

	Data Value Chain			
Role of the public sector	Generation	Collection	Processing	Exchange

Data provider: YES

The public sector provides location data through the base registries

Data Consumer: YES

The public sector consumes location data through the platform

Data Broker: YES

The public sector ensures data access?

Data market "master": YES

The public sector is the intermediate party in case of conflict, and enforces the respect of public value principles

Dimension 2: Role of Location Data and Public Sector actions

Supports or enforces standardisation

Through procurement open data enforce the language of receiving and releasing data

Type	Barriers	Yes	Enablers	Public sector action
Economic	Low demand: Lack of trust in the use cases and technology, value not perceived *Ex: Difficulty to get a business case for an infrastructure (easier for applications)* Lack of trust in investing	***X***	*Cost/benefit Analysis* *ROI set earlier in PS (3 years rather than 10 years as usually foreseen)* *Trust among the involved partners*	Public-private partnerships: *Digital infrastructure is important for government, but some think the market should do that* *Government should take more risk in investment in new technology* *Spread the cost of infrastructure on project, problem of transversal investment* *Triple helix collaboration*
Organisational	Lack of political drive	***X***	*Change culture and management* *General education on Smart Spaces and its benefits* *Make middle management more accountable for flexibility* *Support from the field to explain benefits of change to middle and top management*	*Improve understanding of the value of Smart Spaces amongst decision-makers.* *Raise awareness, showcase value proposition* *Top-down support needed to enforce change in middle management*
	Lack of data Difficulty in accessing data	***X***	*Data platforms* *Availability of sensors for data capture* *Common data capturing devices for multiple systems* *Common approach for measuring, for example, air quality*	*Because of the siloed approach to data ownership, the implementation of a data platform across organisations makes data available* *Encourage "single truth" approaches – similar/comparable data points* *Encourage synergies in hardware for sensors capturing data (there are many poles (light, air, video) in cities)* *Ensure agreement upon a pro-active service on the company side to automatically send the data to the municipality.*

Type	Barriers	Yes	Enablers	Public sector action
			Contractual obligation to deliver data	
Legal	Data Privacy issues	**X**	Legal compliance *Have a data life cycle mgmt. strategy*	Compliance with GDPR and other regulations *Implement a data life cycle management strategy (destroy the data, enforce the right to be forgotten)*
	Legal clarity on data rights	**X**	*Ensure ownership of data by the Public sector to ensure reuse* *The language of the data*	*Clarify data ownership in contractual aspects*
Technical	Lack of trust in investing in technology (ex: Cloud)	**X**	PPP Investment *Penetration of new, third-parties (such as aggregators)*	Public-private partnerships
	Interoperability/ Standards	**X**	*Open, agnostic technologies* *Plugin-based architectures* *Consolidation of standards amongst various industries (i.e. energy, building and ICT sector alliances) – the GEO and BIM worlds still separate*	*Encourage/ enforce usage of MIMs[94] and PPIs[95]* *Open data standards[96]* *Support standards development*
	Lack of skills	**X**	Technology skills for implementing the Smart Space Insufficiently skilled workforce	Public-private partnerships *Outsourcing to university and research institutes* *Training and Skills Acquisition (need digital nativeness)*

[94] Minimal Interoperability Mechanisms (MIMs), see also footnote 43.

[95] Identifying a set of principles for common interfaces (PPI, Pivotal Point of Interoperability) to ensure interoperability also in case of absence of standards or misalignment of available standards, see also https://oascities.org/wp-content/uploads/2018/06/DI224-033-v1-IES-City-IoTWeek2018.pdf

[96] Open data standards include several components and the technical and semantic aspects are the most important. However, the focus should be first on the technical aspects: that you can actually exchange data (this way, a developer can see a house), then decide which part of the semantical aspects need to be discussed. Currently, focussing too much on standardising the semantical aspects upfront creates lots of discussions about cases that may actually never be needed. As long as a developer can see the house, we do not need common standards, there is no need to arrive to the same definition of a house. Technical exchange is important.

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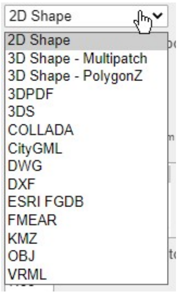
Type	Barriers	Yes	Enablers	Public sector action
	Lack of trust in security		Modular design of IT systems to increase security	Encourage the MIMs approach in the design of systems Introduce various levels of data access to avoid security and privacy issues with potentially sensitive data

Dimension 3: Location data interoperability and exchange			
Use case: 3D Building Information and AR			
Location data exchange capabilities			
Integration styles		ETL (Extraction, Transformation and Loading)	API mediation
(1) Location data set type and standards		 Export of current situation (buildings, trees and other relevant data like pipes and cables) from Rotterdam3D (export tool in Rotterdam3D makes use of FME software1), in the format used by the developer (14 different formats) Key registry of addresses and buildings Large scale topography base map BIM model of new building Generalised version of BIM building for use in VR/AR application.	Shape, GeoJSON, 3D tiles (GLTF) DWG, WFS
(2) Tools		Autodesk suite Paint3D to create 3D tile (GLB) file of building to use in planner tool Rotterdam3D planning and publisher tool Augmented Reality Software	

Location Data – Tools and Standards				
	Data Value Chain			
	Generation	Collection	Processing	Exchange
(1) Location Data Sources	Large Scale Base map	From the surveying department of the municipality to the nation-wide provision		File-based formats like shape, dwg,

	Small Scale base map Key registry of addresses and buildings Key registry of the underground	/infrastructure registration, managed and hosted by the Cadastre		(City) GML or SketchUp. Streaming formats like WFS, WMS
(2) Tools	ArcGIS provides WFS and WMS, and WMTS formats for its data IMGEO (Information Model GEOgraphy) CityGML ArcGIS server, Mapserver, Geoserver	ArcMap, ArcGIS Pro, DgDialog. IMGEO INSPIRE GeoJSON GeoTIFF	Processing benefitting from: WFS, WMS SensorThings, MQTT Processing making use of these data standards: GeoJSON, GeoTIFF	GISWEB (internally developed GIS viewer), ArcGIS Online, Obsurv Cesium and multiple viewers compatible with open standards like WFS
	Standards used (this case study did not detail in the Data Value Chain)			
	Generation	Collection	Processing	Exchange
(3) Standards				
Artificial Intelligence				
Smart City and Digital Twin	MIMs[97]: Smart data models, Context Information, Data Marketplace (Ecosystem Transaction Management) CityGML			
Internet of Things	Sensor of Things API - Smart data models - GeoTIFF, GeoJSON			
Event Stream Processing	MQTT [98]			
Building Information Modelling	BIM IFC			
Geospatial standards	WFS, WMS, WMTS			
Open Data Standards	OpenAPI, INPIRE			

[97] Other MIMs will be developed in the future, such as the Open API Strategy. Digital Rotterdam is developing a MIM Geo functionality, providing basic geospatial functionality such as visualising a digital twin, or selecting objects. Rotterdam is named Deputy chairman of city council of OASC, and will develop this in cooperation through the living lab approach. Other areas focused on are the Data Conversion capabilities (Northbound open data standards and Southbound data standards can be different), and (Access to) data storage which is needed to access historical data of a Digital Twin for example. The storage of this historical data is determined by the owners of the data, so an open format is needed to ensure access to this data. The data can be stored in the cloud of the platform, but also by the datasource (and made accessible to the users).

[98] For Northbound, Rotterdam is using Sensorthings API (NGSI might be an option) for sensordata. MQTT is preferred for Southbound as it sends only the minimal signal – a small data pulse is preferred for large mounts of data to be transferred fast, but only transmits a small piece of information (e.g.: 39). Sensorthings API – OGC provides good metadata information (39 is the temperature). SoT API gives good meta information info = 39 is the temperature, but if it is used on the Southbound, you send also all the meta information with it so slows it down. They are experiencing using MQTT with a SoT API "meta information piece in between stored at the platform.

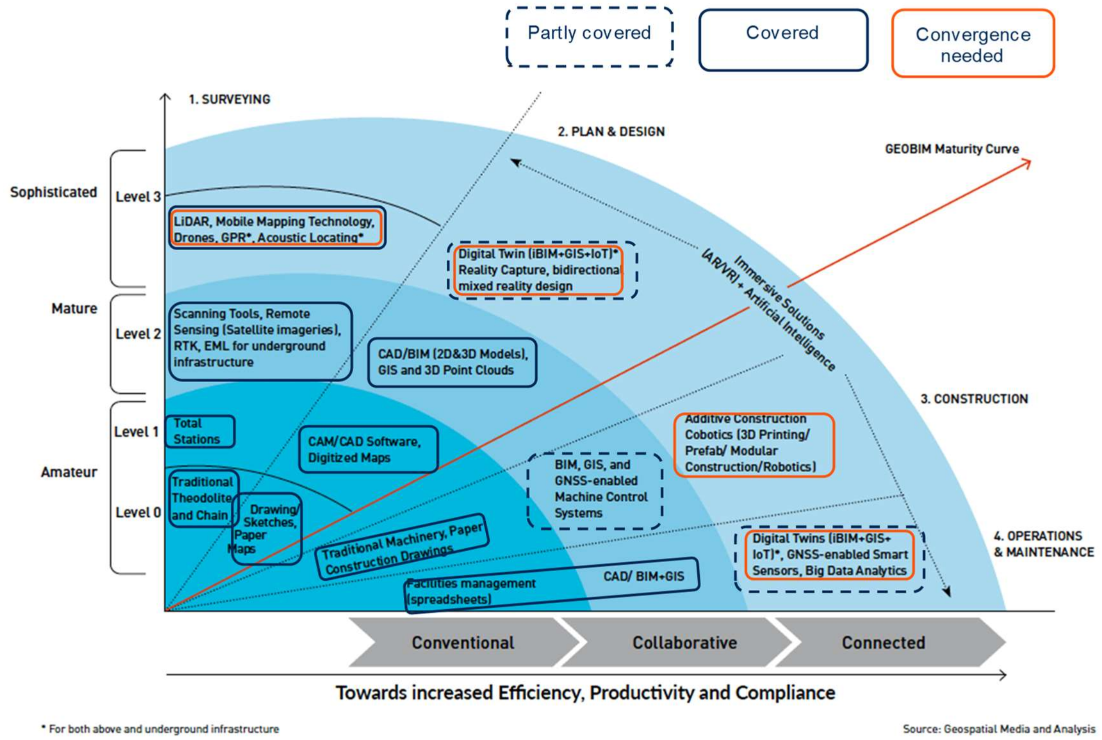
Dimension 4: Smart Space maturity and components

Smart Space Maturity Level

This case study tested the GEOBIM Maturity model[99], used to evaluate and assess the ability of an architecture, engineering and construction (AEC) firm to operate in a collaborative and connected data environment. The GEOBIM Maturity Model ranges from Level 0 to 3 and beyond as more innovation takes place in the GEOBIM technology ecosystem. The integration of geospatial and BIM technologies becomes an 'accepted' definition across the construction lifecycle. The GEOBIM Maturity Model – cuts across the construction lifecycle of surveying, plan and design, construction and operations and maintenance.

The maturity assessment is done by highlighting the levels in the figure below according to the provided legend.

Figure A.1. Maturity model for Smart Spaces



99 See the GEOBIM MARKET IN AEC INDUSTRY report, Maturity Model accessed from the Web in May 2020, https://geospatialmedia.net/reports/geobim-market-in-aec-industry-report/

Smart Space Component Category	Component description
Data Sources	
Static data	IFC (International Foundation Class) BIM file format City GML uploaded into the platform and exposed as an API Traffic data
Dynamic data	Sensor data Mapping data from sensor data is currently in the 1st mvp
Location data	Cadaster data ESRI ArcGIS Sensor data
Data capturing devices	IoT Sensors LIDAR technologies Mobile applications
Cloud	All the solutions are cloud-based
Public	
Private	Cloud service provider solution of public cloud, but hosted on own private network Microservice architecture – set of several private networks interacting together. Zero-trust architecture.
Analytics	
Location Intelligence	Not yet in the current mvp Location data exposed to APIs Public and private use cases are input for the further development of the platform
Identity and Access Management (IAM)	
	Identity governance and administration component Privilege Access Management Component Access Management Component Identity provider Identity broker Tools from the City of Rotterdam – tenant from the existing tools used for the Platform.(this is in Procurement phase) Within the context of the MIM on privacy and security.
Data Storage	
	Within the context of the Data Storage MIM Planned, not yet in the current mvp

Integration and interoperability	
API Gateway	The core engine of the platform Planned, not yet in the current mvp Probably the one provided by the Cloud Service Provider Within the context of the Interconnectivity MIM
IoT Gateway	Planned, not yet in the current mvp Probably the one provided by the Cloud Service Provider Within the context of the Interconnectivity MIM
Context Broker	Planned, not yet in the current mvp
ESB	Yes, probably the one provided by the Cloud Service Provider within the context of the Interconnectivity MIM
MIMs	• Context Information Management, • Smart Data models, • Data marketplace Rotterdam is developing additional MIMs • 3D Digital Twin • Privacy & Security Management • Geo Functionality • Data Storage • Open API strategy • Data conversion • Interconnectivity
Platforms	
Digital Twin	
Urban Platform	
other	
Formalised Ecosystems	
OASC	Yes, supporting the development of additional MIMs
FIWARE	Currently analysing its use
OGC	
Other	

Annex 3. The Urban Platform of the city of Guimarães (PT)

The Urban Platform of the city of Guimarães (PT)			
Name Urban platform of Guimarães		URL https://www.ubiwhere.com/en/news/ubiwhere-established-the-urban-platform-in-guimaraes-a-good-practice-supported-by-the-european-commission	
Lead Organisation Name Ubiwhere		Lead Organisation Category Private sector	
Description The Guimarães City Council, through the Division of Intelligent and Information Systems, is implementing an Urban Intelligence Platform to obtain answers to daily challenges through digitalisation based on data collected in an urban environment.			
Administrative level Sub-national, City	Geographic coverage Portugal	Start Date 2019	Still Active Yes

Dimension 1: Location intelligence contribution to public value in Smart Spaces		
Example Use Case	**Location intelligence type**	**Type of decision making and impact**
Efficient Route Planning	(1) descriptive analytics that uses data to describe, summarise and visualise information, as well as mining and aggregating current and historical data to gain insight (3) prescriptive analytics that recommends courses of actions to achieve an outcome by making decisions. **Location analysis:** selecting the optimal location for the origin and destination points when designing transportation routes to optimise the service coverage **Matching:** association between traffic flow conditions and traffic incidents (from real-time monitoring solutions) and road attributes (from GIS systems) based on their current context and state to classify the weight (i.e. a numeric value in a scale that helps determine how suitable that segment is when tracing a route) of a certain road segment **Trajectory tracking:** Monitor the itineraries performed by the vehicles in conjunction with the planned itineraries to learn movement patterns and optimise the route planner patterns	**Type of decision making:** - Strategic **Impact:** - Short term

Public Value of the use case			
Economic and financial value (Inc. Efficiency)	**Citizen value and user attractiveness** (incl. Social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. Transparency)

- Medium	- High	- High	- High

Example Use Case	Location intelligence type	Type of decision making and impact
Real Time Vehicle Location tracking	(1) descriptive analytics that uses data to describe, summarise and visualise information, as well as mining and aggregating current and historical data to gain insight (2) prescriptive analytics that recommends courses of actions to achieve an outcome by making decisions. **Location analysis:** selecting the optimal location for the origin and destination points when designing transportation routes to optimise the service coverage **Matching:** association between traffic flow conditions and traffic incidents (from real-time monitoring solutions) and road attributes (from GIS systems) based on their current context and state to classify the weight (i.e. a numeric value in a scale that helps determining how suitable that segment is when tracing a route) of a certain road segment **Trajectory tracking:** Monitor the itineraries performed by the vehicles in conjunction with the planned itineraries in order to learn movement patterns and optimise the route planner patterns	**Type of decision making:** - Strategic **Impact:** - Short term

Public Value of the use case			
Economic and financial value (Inc. Efficiency)	**Citizen value and user attractiveness** (incl. Social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. Transparency)
- High	- Low	- High	- Low

Example Use Case	Location intelligence type	Type of decision making and impact
Disasters/ Catastrophe Management & Response	(1) descriptive analytics that uses data to describe, summarise and visualise information, as well as mining and aggregating current and historical data to gain insight (2) predictive analytics (3) prescriptive analytics that recommends courses of actions to achieve an outcome by making decisions. Context-Aware Recommendation System, Matching, Predictive Analysis, Location Based Relationship, POI Recommendation	**Type of decision making:** - End-user **Impact:** - Short term

Public Value of the use case			
Economic and financial value (Inc. Efficiency)	**Citizen value and user attractiveness** (incl. Social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. Transparency)

- High	- High	- High	- High

Dimension 2: Role of Location Data and Public Sector actions			
Data Value Chain Steps			
Generation	**Collection**	**Processing**	**Exchange**
Data acquisition Information is captured in a digital format from devices	Data organisation: collection and validation Collection and consolidation of data from multiple sources. Comprises checking of the data accuracy before integration into a valid dataset.	Data processing and analysis Processing of data to generate insight using identification of patterns in the data, including descriptive, predictive and prescriptive analytics.	Data sharing and publishing Data is shared and published (through APIs, data portals, for example) to be used. At this stage, it can also be reused or repurposed.

Role of location data	Data Value Chain			
	Generation	Collection	Processing	Exchange
Location Data is the service: Location data or location intelligence algorithms are the main value-generating component of a service. Example: navigation service		X		X
Location data is the service at collection and exchange levels to identify the real-time vehicle location or some occurrence/catastrophe that took place. To develop an efficient route between a vehicle location and incident (disaster), other information about traffic congestions and road incidents or roadworks (and their location) are taken into account in the dynamic planning of the itinerary Collection: Matching road segment attributes (no. lanes, pavement, authorised vehicles, speed rules) with other data (traffic flow, incidents) Exchange: Making the road conditions data available to the community through open APIs and/or open data portals				
Location Data adds intelligence Location data or location intelligence algorithms enrich the value generated by products or services. Example: location-based advertising. Location intelligence algorithms are analysing location data to make the product or service offering more intelligent. Example: Shortest route calculation			X	
Processing: Information is linked to its geographic context (e.g. road segment, POI, building, parish, district, etc.) both at the edge and the cloud to identify the right stakeholder to invoke (both geographically and operationally) and determine the potential priority in responding				
Location Data supports data validation activities: Location data is used to validate other sets of data. Example: Location data in lampposts validate earthquake information identified by other data	X		X	

Generation: Capturing catastrophic data (e.g. temperature and pollutants sensors or cameras for wildfires, accelerometer for earthquakes) with geolocated sensors that provide information in real-time

Processing: Geolocated sensors are linked to computing units in street furniture (e.g. lampposts) at the edge that pre-validate and raise alarms to ensure a proper response

Role of the public sector	Data Value Chain			
	Generation	Collection	Processing	Exchange
Data provider	X		X	X
Generation: Implement/ Acquire systems to monitor real-time parking, weather conditions, etc. (sensors, IoT devices, etc.)				
Processing: Ensuring anonymisation of sensitive information through hashing and trimming and limiting time periods of access				
Exchange: Ensuring data access or open standard interface				
Data Consumer			X	X
Processing: Privacy-preserving mechanism and tools				
Exchange: Ensuring data access				
Data Broker				X
Exchange: Ensuring data access				
Data Owner				
N/A (the case study template did not provide this option at the time)				
Supports or enforces standardisation		X	X	X
Collection, Processing and Exchange: Standardised access to data and APIs				
Through the procurement process, the public authorities require the provision of open standards (typically FIWARE / NGSI-LD), but it depends on the context of the use case.				

Enablers and barriers of a Smart Space and location intelligence, and related public sector actions				
Barriers		**Yes**	**Enablers**	**Public sector action**
Economic	Lack of funding, uncertainty relating to hidden costs	**X**	Financing/ Funding	Public-private partnerships
	Low demand: Lack of trust in the use cases and technology, value not perceived	**X**	Cost/benefit Analysis	Public-private partnerships
Organisational	Lack of political drive	**X**		Raise awareness, showcase value proposition
	Need for orchestration and maintenance of new and legacy technology	**X**	Openness	Open standards compliance as a requirement in all tenders

	across many manufacturers			Best practices on open-source and open APIs for data integration from legacy systems (cf. example on traffic from inductive loops)
	Lack of data Difficulty in accessing data	**X**	Marketplaces and communities	Launch procurement for acquisition or digitisation of new data sets, or applications, and ensuring the data owner is the public sector and the provider complies with open standards and open data (when applicable) Engage citizen community with data sharing Promote data marketplaces and partner with schools and universities
Legal	Data Privacy issues	**X**		Compliance with GDPR and other regulations
Technical	Lack of computation capacity	**X**	Data spaces	Public-private partnerships Procurement for IT computation
	Lack of innovative technology (ex: real-time data sharing)	**X**	PPP investment	Public-private partnerships Procurement for new services
	Lack of trust in investing in technology (ex: Cloud)	**X**	PPP Investment	Public-private partnerships Training and Skills Acquisition
	Network un-reliability			
	Interoperability/ Standards Usage of older OT assets that lack integration, data acquisition and ingestion standards	**X**		Open standards compliance as a requirement in all tenders to avoid this issue in the future. See the example below of the usage of NGSI-LD to ensure that the new data set that has been "translated" (custom work) from legacy systems to be reused

Example of NGSI-LD Compliance for orchestration of legacy and new systems for smart mobility. This approach provides integration potential of the platform with traffic systems like Gertrude or similar that manage traffic lights and can count vehicles from inductive loops.

Data model TrafficFlowObserved: https://swagger.lab.fiware.org/?url=https://smart-data-models.github.io/dataModel.Transportation/TrafficFlowObserved/swagger.yaml

This data model allows identifying traffic flow observations (counting cars) with modern traffic sensors, CCTV equipment with computer vision, and legacy inductive loops.

	Lack of skills			Public-private partnerships Training and Skills Acquisition
	Lack of trust in security			Public-private partnerships Training and Skills Acquisition

Dimension 3: Location data interoperability and exchange

Use case: The Urban Platform is a solution that gathers data from quite different types of sources. This data can come from sensors, other platforms and services (via APIs) or even directly from the citizens (or communities), who provide feedback through mobile apps, surveys, and information systems. To enable multichannel communication tools, open communication and data exchange standards are key.

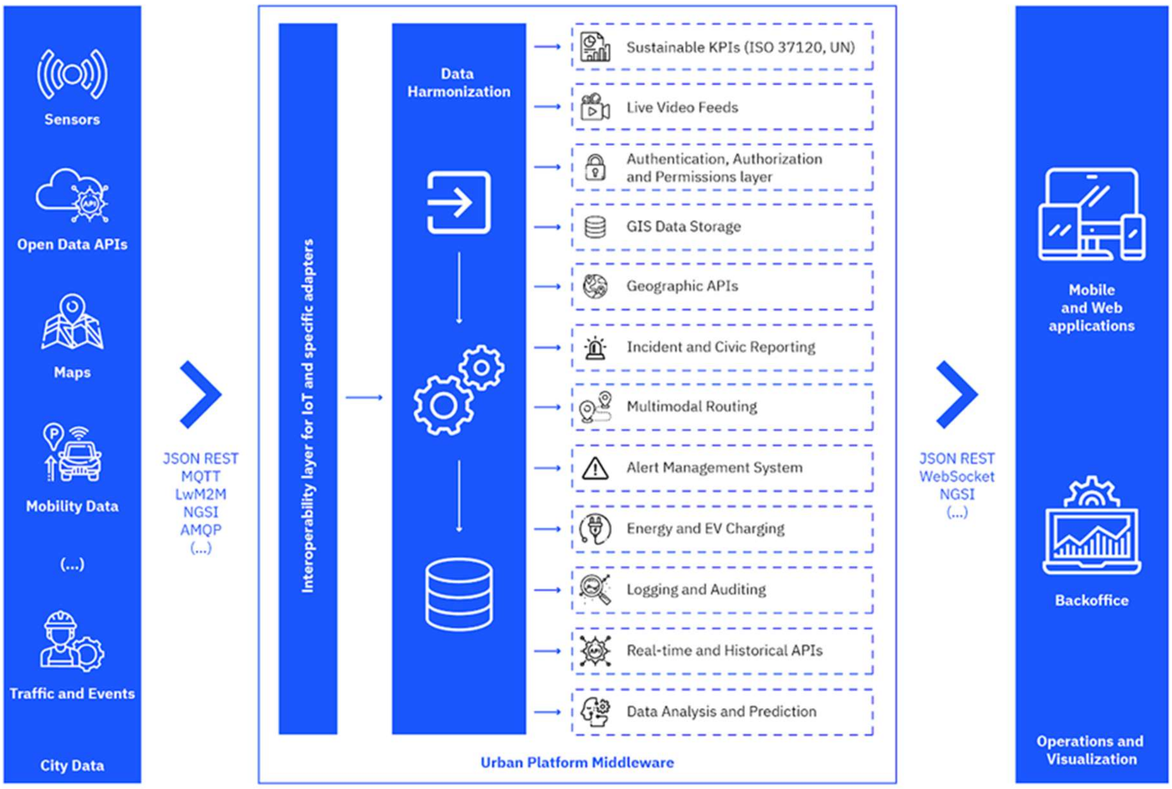
Ubiwhere's experience with open standards and harmonised data models, such as FIWARE's NGSI and Smart Data Models, has been used in building the Urban Platform, giving it a competitive advantage.

Its interoperability layer enables data collection through different protocols and standards, while the harmonisation layer leverages smart data models and ontologies for harmonisation.

Another important aspect is that this makes it easier for cities to increase their perceived transparency towards their citizens by making it very simple to have any data they choose to be openly available.

An overview of the architecture is provided in the figure below.

Figure A.2. Architecture overview[100] of the Urban Platform of Guimarães



Use Case: Efficient Route Planning - collecting traffic flow observations, road incidents, route planning requests

[100] Source: documentation provided by Ubiwhere.

Dimension 3: Location data interoperability and exchange			
Location data exchange capabilities			
Integration styles	ETL (Extraction, Transformation and Loading)	API mediation	Message-Driven Architecture / Stream Processing
(1) Location data set type and standards	Road structure (ordered list of nodes normally linked to at least one tag - e.g. maxspeed=50 - or being included within a Relation - e.g. route=bus) Cadaster data integrated from ESRI ArcGIS or OpenStreetMaps and OpenStreetBuildings	Route planning request (e.g. GET /route/v1/driving/13.388860,52.517037;13.397634,52.529407) REST API, tuple of coordinates compliant with GeoJSON, optional compliance with NGSIv2 and NGSI-LD	Road incidents {"id":922,"event_type":"some_category","event_subtype":null,"status":"Received","severity":"Unknown","attachments":[],,"ongoing":true,"created_by":null,"headline":null,"short_headline":null,"geography":{"type":"Point","coordinates":[-8.296078518033028,41.424972839358574]},"start_date":"2021-05-10T12:04:00+01:00","finish_date":null,"description":"some_description","image_url":"https://www.cm-guimaraes.pt/cmguimaraes/uploads/citizen_issue/image/660/file_from_app_606.jpeg","address":"Avenida do Centro Escolar, Urgezes, Guimarães, Braga, Ave, Norte, 4810, Portugal","total_updates":1,"citizen_submitted":true,"answered_by":null,"created_at":"2021-05-24T11:27:43.061045+01:00","updated_at":"2021-05-31T18:50:12.525738+01:00","assignee":null} Open511 and Open311 data models compliant with GeoJSON, NGSIv2 and NGSI-LD
(2) Tools	Apache Airflow, PostgreSQL and PostGISX	Open-source route planning services	Orion Context Broker, RabbitMQ, Scorpio Broker

Location Data – Tools and Standards				
	Data Value Chain			
	Generation	Collection	Processing	Exchange
(1) Location Data Sources	ESRI ArcGIS OpenStreetMaps OpenStreetBuildings	from cadastre data		
(2) Tools	Orion Context Broker Scorpio (NGSI-LD)	GeoJSON GeoTIFF SiRi / NeTEX NGSI / NGSI-LD	Processing of data that is exchanged using these standards: GeoJSON GeoTIFF	GeoJSON NGSI-LD
	Data Value Chain			
	Generation	Collection	Processing	Exchange

(3) Standards				
Artificial Intelligence			Standard needed	Standard needed
Smart City and Digital Twin Open Agile Smart Cities MIMs		Context information NGSI and NGSI-LD	Smart Data models	Data Marketplace
Smart City and Digital Twin other			SAREF4City CityGML	CityGML
Internet of Things		NGSI / NGSI-LD oneM2M (implemented with openMTC) GeoJSON GeoTIFF	Smart Data Models SAREF SAREF4City	NGSI / NGSI-LD oneM2M GeoJSON GeoTIFF
Event Stream Processing		NGSI / NGSI-LD oneM2M MQTT LwM2M	SiRi / NeTEX	NGSI / NGSI-LD oneM2M MQTT LwM2M
Building Information Modelling			CoBIe	
Open Data Standards Missing: how to structure information in a harmonised way across cities Group of DUTCH cities: CDSM https://www.polisnetwork.eu/news/dutch-cities-develop-new-mobility-data-standard/				Swagger/ Open API CKAN

Dimension 4: Smart Space maturity and components

Smart Space Maturity Level				
Gartner research[101] sees four phases of Smart Spaces underscored by five dimensions.				
Stage	**Phase 1 Isolated Systems**	**Phase 2 Connected Systems**	**Phase 3 Coordinated Systems**	**Phase 4 Intelligent Environments**

[101] Gartner (2019b), see also footnote 23.

Openness	none	Internal	**External**	Fully
Openness. Openness refers to the degree of accessibility to the elements in a Smart Space, including data. In an open model, systems can interact with each other with data exposed and accessible through standardised mechanisms. Trends in open data formats, identifiers and protocols, as well as the work of open-source communities, are driving this aspect of Smart Spaces.				
Connectedness	none	Yes	**Yes**	Yes
Connectedness refers to the depth, breadth and robustness of the connections between the elements in a Smart Space. Connectedness is closely linked to openness. As the mechanisms to access the attributes, data and functions of an application increase, so does the degree of openness. Increasing the granularity of the accessible attributes, data and functions also increases connectedness. Trends such as IoT, IoT platforms, digital twins, edge computing, APIs and API gateways, and mesh app and service architecture all contribute to greater connectedness in a Smart Space.				
Coordination	none	Integration	**Coordination**	Coordination
Coordination refers to the depth and strength of coordination between the elements in a Smart Space. Coordination is a more active aspect of Smart Spaces that builds on connectedness. While connectedness looks at the opportunity to connect various elements, coordination looks at the actual level of interaction and cooperation between the elements. For example, two applications operating in a Smart Space that shared login credentials would have a very low coordination score. However, if they also shared data and had tightly integrated process execution, they would have a much higher coordination score. Trends such as MASA, APIs and events also factor into coordination. Coordination in this context refers not only to technical coordination, but also to the coordination of people and processes based on the underlying technology.				
Intelligence	none	none	**Semi-intelligent**	Intelligent
Intelligence refers to the use of machine learning and other AI techniques to drive automation into the Smart Space and deliver services to augment the activities of people within it. Intelligence can manifest itself in the form of autonomous things or augmented intelligence, including augmented analytics. An important aspect is the use of AI to deliver intelligent multimodal and multidevice immersive experiences to enhance how users perceive and interact with the various elements in the Smart Space.				
Scope	Team	Department	**One organisation**	Ecosystem
Scope refers to the breadth of a Smart Space and its participants. A Smart Space with a very narrow scope might focus on a single team within a department of a large organization. A Smart Space with a broader scope might focus more across the organization but within a bounded problem space. A Smart Space with an even broader scope might include elements external to the organization with an ecosystem of participants. Openness, connectedness and coordination set the stage for increasing the scope of a Smart Space. Intelligence promotes simplified access and automated management as the scope of a Smart Space increases.				

Smart Space Component Category	Component description
Data Sources	
Static data	OpenStreetMaps/cadastre data about the roads, bridges, pathways and sidewalks (just to name a few) of the region, to support geographic and data analysis operations (e.g. most congested roads) as well as geocoding features (i.e. translation of address to coordinate tuples)
Dynamic data	Real-time traffic information (traffic intensity and average velocity) Mobility and Civic Incidents and

	planned roadworks courtesy of the city council and the citizens' community through a mobile application
Location data	Sources: Map tools (OpenStreetMap, ESRI ArcGIS …) Cadastre data Geospatial data provided by the municipality: ❑ Geospatial 3D information about buildings from the proprietary Geographic Information System (GIS). Due to its high volume, this data is updated periodically or on-demand. The energy consumption of the buildings owned by the city is also provided; ❑ Information and geographic boundaries of the administrative regions (e.g. parishes) (can be updated with additional demographic information regarding the zones); Information and geographic representations of watercourses
Data capturing devices	Mostly Sensors, video, mobile applications
Cloud	
Public	Hosting the cloud services for data collection, extract-transform-load, and intelligent services like route planning and incident reporting
Private	For data storage for sensitive data and backups
Analytics	
Location Intelligence	The platform performs cross-domain analysis – such as the impact of one occurrence to the different domains of its surrounding area (e.g., how a large event such as a music concert has impacted the traffic and parking and, additionally, how the generated traffic affected air quality and noise in those areas). One of the intelligent services is to compute the best route for an emergency vehicle to efficiently reach an occurrence avoiding congestion, taking into account the current state of the traffic and the characteristics of the road, as certain vehicles need to comply with certain restrictions. These routes should be obtained in a short amount of time, with computations being updated whenever there is a change in the road network status
Integration and interoperability	
API Gateway	Yes, for authorisation and API management
Context Broker	Yes, to comply with MIM1 (Context Information Management) via Orion and Scorpio
ESB	No
MIMs	Context Information Management, Smart Data models, optional data marketplace
Platforms	
Digital Twin	

Urban Platform	Ubiwhere
other	
Formalised Ecosystems	
OASC	Ubiwhere was part of the Synchronicity project where it helped OASC create the MIMs, and the Urban Platform is today part of the CityxCity Catalogue (https://catalogue.city/en/products/urban-platform-a-single-integrated-view-of-our-smart-cities) as one of the best examples of solutions compliant with OASC MIMs. Ubiwhere is not yet an official partner of OASC.
FIWARE	Ubiwhere is a gold member of FIWARE Foundation and a FIWARE Impact Story https://www.fiware.org/wp-content/uploads/FF_ImpactStories_Ubiwhere.pdf
ETSI	Ubiwhere is a full member of ETSI, having joined in 2017 to contribute to the industry with its R&D results in the format of specifications and use cases, as well as to share its telecom and smart cities know-how and perspectives, concretely in industry specification groups such as CIM (Cross-cutting Context Information Management), MEC (Multi-Access Edge Computing), ZSM (Zero touch network & Service Management) and OSM (Open Source MANO) just to name a few. Ubiwhere has been collaborating in four Specialist Task Forces, linked with its domains of expertise: STF561 (Smart cities and communities: standardisation to meet citizen and consumer requirements), STF551 (MEC Testing Framework) and STF569 (Testing Framework for Multi-Access Edge Computing) and STF584 (Artificial Intelligence for IoT Systems).
Other	

Annex 4. Pametna Mlaka (SI)

Pametna Mlaka (SI)	
Name Smart neighbourhood Mlaka of city of Kranj	URL https://www.youtube.com/watch?v=HbclFfj9lkw
Lead Organisation Name 3fs (technical lead), Riko (infrastructure company – coordinator and project lead), Municipality of Kranj	Lead Organisation Category Private-public sectors

Description
The City council of Kranj has created a business playground with a straightforward call to action: innovative companies. We are here to lower the barriers of innovation and integration for you to develop your bleeding edge smart city concepts and solutions ready for the future. The result is a "public cloud first" smart city solution, developed in a lean and agile way and in a symbiotical relationship of city council and leading IoT innovation companies.

Administrative level	Geographic coverage	Start Date	Still Active
Sub-national, City	Slovenia, Gorenjska region	2020	Yes

Dimension 1: Location intelligence contribution to public value in Smart Spaces

Example Use Case	**Location intelligence type**	**Type of decision making and impact**
Digital twin POC through augmented reality	(1) **descriptive analytics** that uses data to describe, summarise and visualise information, as well as mining and aggregating current and historical data to gain insight: as future capability: simulation of input changes through maximum tangibility (**augmented reality**) (2) **predictive analytics** that uses machine learning with data to make predictions and uses statistical and probabilistic techniques to predict future trends and outcomes; - drag the timeline into the future	**Type of decision making:** - Strategic **Impact:** - Long term

Public Value of the use case

Economic and financial value (inc. Efficiency)	**Citizen value and user attractiveness** (incl. Social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. Transparency)
Low (for the citizen) High (for the city) (in distant future	High	Low High (in distant future)	None (currently, only 3 devices)

Example Use Case	**Location intelligence type**	**Type of decision making and impact**

Map based dashboard with ML prediction and reference point capabilities	(2) **predictive analytics** that uses machine learning with data to make predictions and uses statistical and probabilistic techniques to predict future trends and outcomes;	**Type of decision making:** - Strategic **Impact:** - Long term

Public Value of the use case			
Economic and financial value (inc. Efficiency)	**Citizen value and user attractiveness** (incl. Social, environmental sustainability)	**Administrative value and effectiveness** (incl. innovation and quality)	**Democratic value and trust** (incl. Transparency)
Medium	Low	High	Medium

Dimension 2: Role of Location Data and Public Sector actions

Selected use case name:

Data Value Chain Steps			
Generation	**Collection**	**Processing**	**Exchange**
Data acquisition Information is captured in a digital format from devices	Data organisation: collection and validation Collection and consolidation of data from multiple sources. Comprises checking of the data accuracy before integration into a valid dataset.	Data processing and analysis Processing of data to generate insight using identification of patterns in the data, including descriptive, predictive and prescriptive analytics.	Data sharing and publishing Data is shared and published (through APIs, data portals, for example) to be used. At this stage, it can also be reused or repurposed.

	Data Value Chain			
Role of location data	Generation	Collection	Processing	Exchange
Location Data is the service: Location data or location intelligence algorithms are the main value-generating component of a service. Example: navigation service	X	X	X	X

Generation: Location data is a key component of the platform. Locations of all metering points are currently pre-configured in a central catalogue (provisioning process).

Collection: Metering points send data using various technologies (AMQP, MQTT…). All measurements include metadata with meter ID which is used to resolve specific location data.

Processing: Current location-based processing is done through data consolidation and statistics services (SUM, MAX, AVG…)

Exchange: Location-based data is available through API through the developer's portal as well as clients (Digital Twin, Map based dashboard)

Location Data adds intelligence Location data or location intelligence algorithms enrich the value generated by products or services. Example: location-based advertising. Location intelligence algorithms analyse location data to make the product or service offering more intelligent. Example: Shortest route calculation			X	X
Processing: In the data processing pipelines, we currently use baseline machine learning and other AI technologies to enable smart alerting in real-time and baseline predictivity of sensory data Exchange: Smart features like aggregated context-aware data, alerting hooks, can be exposed through APIs as well as clients through API/developer portal				
Location Data supports data validation activities: Location data is used to validate other sets of data. Example: Location data in lampposts validate earthquake information identified by other data	X		X	X
Generation: Multiple Geolocated metering points/sensors send data in “real-time”. Processing: Data from multiple geolocated metering points/sensors can be crosschecked to ensure data validity. The processed information can then also be verified by other external services. Exchange: To ensure information validity and accuracy, raw data can also be retrieved using APIs by 3rd party clients.				

	Data Value Chain			
Role of the public sector	Generation	Collection	Processing	Exchange
Data provider	X		X	X
Generation: Provision metering points/sensors (owned/ rented by the Municipality) to send real-time data to the Smart Mlaka platform. Processing: Data is being processed and stored securely with all the necessary legal compliance (such as GDPR) by the platform, which is owned by the municipality. For new applications that will use the data, the processing will be done by the owner of the application developed using the platform. Exchange: Location-based data is accessible using APIs and is ready to be sent to the government public data portal				
Data Consumer			X	X
Processing: Data consumers – including the public sector - must process and store data using industry-standard security mechanisms? Personalised and metering data should be as decoupled as possible – e.g. weakly linked by an anonymised correlation. They consume it through the APIs exposed - after security services are applied - on the developer’s platform. Exchange: Authorized and authenticated data consumers can retrieve pre-defined sets of data using industry-standard security mechanisms and end-to-end encryption.				
Data Broker				X
Exchange: Appropriate bi-directional, subscription-based data access. Location-based data is accessible using APIs and is ready to be sent to the government public data portal				
Data Owner	X	X	X	X

Generation: Provision metering points/sensors to send real-time data to the Smart Mlaka platform. Other sources of data from various branches of the municipality. Via IoT platforms or just structured/unstructured Data Bases

Collection: In the case of Smart Mlaka, the municipality is the collector of data on the Smart Mlaka platform. Collecting all of the input data on data lake structure allows applying rules for data retention policies. The notion of exit strategy/ lock-in is on the table.

Processing: as above

Exchange: as above

Supports or enforces standardisation	X	X	X

Collection, Processing and Exchange: Standardised access to data and APIs. Through the procurement process, the public authorities require the provision of open standards (typically FIWARE / NGSI-LD), but it depends on the context of the use case.

Enablers and barriers of a Smart Space and location intelligence, and related public sector actions

	Barriers	Yes	Enablers	Public sector action
Economic	Lack of funding: the project is in pilot phase - not receiving funding from the public sector	X	Research budgets Public funding	Public-private partnerships Private companies have an innovation budget that can be used for piloting. In Slovenia, there are several public tenders[102] for municipalities in MVP stages funded by the public sector
	Low demand: Lack of trust in the use cases and technology, value not perceived	X	Minimal Viable Product approach in piloting	Public-private partnership in pilots
Organisational	Lack of political drive		Visibility	Raise awareness, showcase value proposition
	Need for orchestration and maintenance of new and legacy technology across many manufacturers		Openness	Open standards compliance as a requirement in all tenders Best practices on open-source and open APIs for data integration from legacy systems
	Lack of data Difficulty in accessing data	X	Municipality and agencies, companies and NGOs open their data	Increase IT competitiveness of municipality Promote "municipality as a service" architecture[103] Promote data marketplaces
Legal	Data Privacy issues	X	Regulations	Compliance with GDPR and other regulations

102 See, for example, Slovenia: Public tender for demonstration projects for the establishment of smart cities and communities "JR PMIS" that was published on 12 February 2021 by the Ministry of Public Administration, https://www.gov.si/zbirke/javne-objave/javni-razpis-za-demonstracijske-projekte-vzpostavljanja-pametnih-mest-in-skupnosti-jr-pmis/

103 This approach aims to ensure that all services provided by the platform should have the same level of maturity, and be able to serve any client with the same level of quality, whether it is a developer wanting to use data to create a visualisation app or the municipality using it to deliver a service.

Enablers and barriers of a Smart Space and location intelligence, and related public sector actions			
Technical	Lack of computation capacity	Partnerships Data spaces	Collaboration models Procurement for IT computation
	Lack of innovative technology (ex: real-time data sharing)	Partnerships	Innovation collaboration models
	Lack of trust in investing in technology (ex: Cloud)	Partnerships	Innovation collaboration and risk-sharing models Training and Skills Acquisition
	Interoperability[104]	Standards	Open standards compliance in procurement
	Lack of skills	Training Partnerships	Public-private partnerships Training and Skills Acquisition
	Lack of trust in security		Partnerships and Skills Acquisition

Dimension 3: Location data interoperability and exchange

Data is provided by various metering points, IoT Devices, sensors, other smart solutions, and arbitrary 3rd party services. Currently, as an MVP designed bottom-up and a technology stacks solution, Smart Mlaka offers different data-ingress endpoints (MMQT, AMQP, and REST). Data schemas are a combination of standard or proprietary. Therefore, multiple custom agents (microservices) verify, parse, store and transform received data before it is forward to the context broker. In our MVP case, this broker acts as a baseline broker– it executes processing middlewares for data aggregation, consolidation and normalization. Location data is stored in a central meter/device catalogue; the data pipeline merges it.

Raw data (JSON, XML) is stored in an Azure Data Lake (cloud analytic service for massive parallel data processing) and transformed, normalized data is stored in a PostgreSQL database. Smart Mlaka offers a set of microservices responsible for simple and aggregate data retrieval to access the data. Data is accessible through the REST API Gateway (Azure API Management service), which provides advanced capabilities like caching, load balancing, smart routing, subscriptions & products. API's are available through the Development portal [APIs: List - Microsoft Azure API Management - developer portal (azure-api.net)].

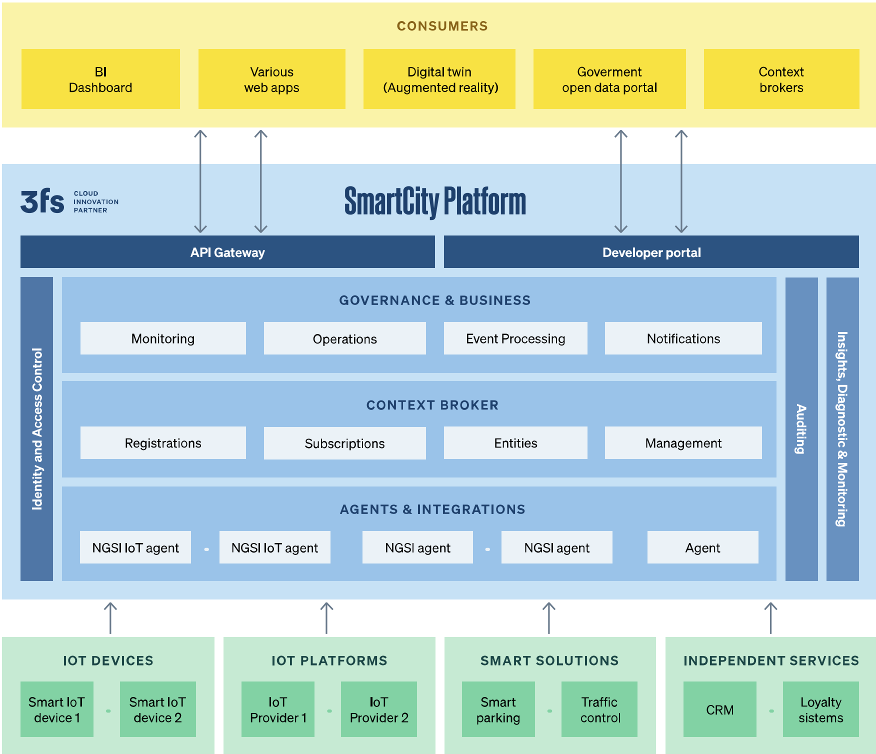
The platform also provides auditing, real-time diagnostics, monitoring (Azure Application Insights) and alerts in case of degraded performance/errors.

As planned and prepared, a central context broker will be implemented using the FIWARE NGSI v2 specification [fiware-ngsiv2-2.0-2018_09_15]. Data providers will be able to connect to the standardized NGSI v2 IoT Agents, and asynchronous integrations using subscriptions will be possible. Standardised data models, context data interfaces and context availability interfaces will ease the integration and enable modern services and automated data exchange.

An overview of the solution is provided below.

[104] For new systems as well as for usage of older OT assets that lack integration and data acquisition standards.

Figure A.3. Pametna Mlaka solution overview



Location data exchange capabilities									
Integration styles	Managed file transfer	ETL (Extraction, Transformation and Loading)	Data virtualisation	Change data capture	Stream Processing	Event-driven architecture	Message-Driven Architecture	API mediation	Service-oriented architecture
(1) Location data set type and standards					RabbitMQ (AMQP)Microsoft Orleans and Orleankka	Proprietary Event. Sourcing framework, CQRS	CQRS – commands, queries and events are messages, integration of managed Azure IoT hub in the future Sample: https://smart-city-apim.developer.azure-api.net/api-details#api=energy&oper	REST, Web Socket, Open API, Compliance with NGSI v2 in the future	

							ation=get-electricity-data		
(2) Tools		Azure Data Lake, Azure CosmosDb, PostgreSQL			RabbitMQ (AMQP), Proprietary framework that uses event and command streams.		Azure API Management		

Location Data – Tools and Standards

	Data Value Chain			
	Generation	Collection	Processing	Exchange
(1) Location Data Sources	Metering Catalogue (list of all registered devices which are data providers)	3rd party services (ex: waste treatment company co-owned by the municipality) transfer data to the Mlaka. GIS Information from the municipality. Data from OPSI (open data portal) is used, and the platform is contributing back (ex parking places)		
(2) Tools	Standardised (location data) and industry-standard protocols (AMQP, MQTT, REST). NGSI v2 with Context Broker in the future	Custom schemas and industry-standard protocols (AMQP, MQTT, REST). NGSI v2 with Context Broker in the future	JSON, XML, binary, Apache Spark and Hadoop, Azure Data Lake	REST, Web Socket Ready for: NGSI v2 endpoints
	Data Value Chain			
	Generation	Collection	Processing	Exchange
(3) Standards				
Artificial Intelligence				
Smart City and Digital Twin				
Internet of Things		MQTT, AMQP, REST endpoints	Proprietary data processing pipelines and services. NGSI ready	REST, Web Socket Ready for: NGSI v2 endpoints
Event Stream Processing		MQTT, AMQP,	Proprietary Events-Sourcing framework with CQRS.	Ready for: NGSI v2 endpoints
Building Information Modelling				
Open Data Standards	The data provided by the municipality is INSPIRE compliant, and the data and services are based on OGC standards			Open API [https://smart-city-apim.developer.azure-api.net/]

Dimension 4: Smart Space maturity and components				
Smart Space Maturity Level				
Gartner research[105] sees four phases of Smart Spaces underscored by five dimensions.				
Stage	**Phase 1 Isolated Systems**	**Phase 2 Connected Systems**	**Phase 3 Coordinated Systems**	**Phase 4 Intelligent Environments**
Openness	none	Internal	**External[106]**	Fully
Openness. Openness refers to the degree of accessibility to the elements in a Smart Space, including data. In an open model, systems can interact with each other with data exposed and accessible through standardised mechanisms. Trends in open data formats, identifiers and protocols, as well as the work of open-source communities, are driving this aspect of Smart Spaces.				
Connectedness	none	Yes	**Yes**	Yes
Connectedness refers to the depth, breadth and robustness of the connections between the elements in a Smart Space. Connectedness is closely linked to openness. As the mechanisms to access the attributes, data and functions of an application increase, so does the degree of openness. Increasing the granularity of the accessible attributes, data and functions also increases connectedness. Trends such as IoT, IoT platforms, digital twins, edge computing, APIs and API gateways, and mesh app and service architecture all contribute to greater connectedness in a Smart Space.				
Coordination	none	Integration	**Coordination**	Coordination
Coordination refers to the depth and strength of coordination between the elements in a Smart Space. Coordination is a more active aspect of Smart Spaces that builds on connectedness. While connectedness looks at the opportunity to connect various elements, coordination looks at the actual level of interaction and cooperation between the elements. For example, two applications operating in a Smart Space that shared login credentials would have a very low coordination score. However, if they also shared data and had tightly integrated process execution, they would have a much higher coordination score. Trends such as MASA, APIs and events also factor into coordination. Coordination in this context refers not only to technical coordination, but also to the coordination of people and processes based on the underlying technology.				
Intelligence	none	**none**	Semi-intelligent	**Intelligent[107]**
Intelligence refers to the use of machine learning and other AI techniques to drive automation into the Smart Space and deliver services to augment the activities of people within it. Intelligence can manifest itself in the form of autonomous things or augmented intelligence, including augmented analytics. An important aspect is the use of AI to deliver intelligent multimodal and multidevice immersive experiences to enhance how users perceive and interact with the various elements in the Smart Space.				
Scope	Team	Department	One organisation	**Ecosystem[108]**
Scope refers to the breadth of a Smart Space and its participants. A Smart Space with a very narrow scope might focus on a single team within a department of a large organization. A Smart Space with a broader scope might focus more across the organization but within a bounded problem space. A Smart Space with an even broader scope might include elements external to the organization with an ecosystem of participants. Openness,				

105 Gartner (2019b), see also footnote 23.
106 Data is shared on the OPSI platform (Open Data Portal).
107 The Proof of Concept demonstrates how intelligent it could be in the future.
108 The developers can use the machine learning capabilities, but not the virtual reality use case.

connectedness and coordination set the stage for increasing the scope of a Smart Space. Intelligence promotes simplified access and automated management as the scope of a Smart Space increases.

Smart Space Component Category	Component description
Data Sources	
Static data	
Dynamic data	Raw measurements
Location data	IoT Sensors External IoT Platform that connects to IoT sensors (ex: data from electricity is gathered from the Electricity provider)
Data capturing devices	A variety of sensors (electricity, water, gas, traffic, environment…) OpenWeatherAPI
Cloud	
Public	Microsoft Azure
Private	
Analytics	
Location Intelligence	Microsoft Azure Machine Learning The analytical tool is the dashboard The solution is ready for smart services – such as traffic jam detection The solution has implemented air quality degradation measurement in specific areas
Integration and interoperability	
API Gateway	Microsoft Azure API Management
Context Broker	Ready for, not fully implementing NGSI v2
ESB	Microsoft Azure Service Bus (publish/subscribe)
MIMs	
Platforms	
Digital Twin	AWAKE digital twin platform creates a virtual city (Proprietary to 3fs, initially made for medical technology sector, as a HoloLens-based simulation solution)
Urban Platform	
other	
Formalised Ecosystems	
OASC	
FIWARE	Yes
OGC	
Other	

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