IN-HABIT - INclusive Health And wellBeing In small and medium size ciTies

D7.6 IN-HABIT FULL OPERATIVE DATA PLATFORM

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Executive Summary

IN-HABIT (INclusive Health And wellBeing In small and medium size ciTies) is an EU Horizon 2020 project aiming to investigate how to enhance inclusive health and wellbeing (IHW) in four peripheral small and medium-sized cities (SMSCs): Cordoba (Spain), Riga (Latvia), Lucca (Italy), and Nitra (Slovakia). The project analyses how traditionally undervalued local resources, such as culture, food, human-animal bonds, and the environment, promote Inclusive Health and Wellbeing (IHW) with a strong emphasis on gender, diversity, equity, and inclusion. It employs an integrated approach combining technological, digital, nature-based, cultural, and social innovations in specific urban public spaces with solutions co-designed, co-deployed, and co-managed in collaboration with local stakeholders.

In this scenario, **IN-HABIT** has developed a **Data Platform** to assess the impact of Visionary and Integrated Solutions (VIS) solutions on mental health, socio-economic wellbeing and healthy lifestyles of people in the city areas of intervention. The **IN-HABIT Data Platform** is a unique, open, robust, and scalable interface designed to integrate seamlessly with other applications and APIs. It connects a network of sensors installed across public and private locations in the cities of Cordoba, Riga, Lucca, and Nitra, collecting data from air quality sensors, soil moisture sensors, PAR radiation measurement sensors, cameras and water flow sensors.

The **IN-HABIT Data Platform** features an intuitive and user-friendly dashboard, offering differentiated access to real-time and historical data. Users can apply filters to access information based on sensor types and other parameters. Its inclusive design, featuring a clear visual palette and accessible navigation, ensures its inclusiveness.

Powered by FIWARE technology, the **IN-HABIT Data Platform** enables efficient data collection and analysis through an interconnectivity layer that complies with EU regulations. A dedicated team based in Cordoba oversees the platform, ensuring the accurate and seamless transmission of data from the sensors, as well as maintaining the proper functioning of the sensor network so that researchers, policymakers and selected citizens can access to organised and relevant data.

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Acronyms

ACL	Access Control List
API	Application Programming Interface
CEP	Complex Event Processing
COAP	Constrained Application Protocol
ESRI	Environmental Systems Research Institute
ETL	Extract, Transform and Load
GPRS	General Packet Radio Service
GSMA	Global System for Mobile Communication Association
HTTPS	HyperText Transfer Protocol Secure
IoT	Internet of Things
JSON	JavaScript Object Notation
KPIs	Key Performance Indicators
LDAP	Lightweight Directory Access Protocol
LORA	Long Range Communication Protocol
MQTT	Message Queuing Telemetry Transport
NB-IOT	Narrow Band Internet of Things
NGSI	Next Generation Service Interfaces
OGC	Open Geospatial Consortium
REST	Representational State Transfer
TTN	The Things Network

1. Introduction

IN-HABIT (INclusive Health And wellBeing In small and medium size ciTies) is an EU Horizon 2020 project aiming to investigate how to enhance inclusive health and wellbeing (IHW) in four peripheral small and medium-sized cities (SMSCs): Cordoba (Spain), Riga (Latvia), Lucca (Italy), and Nitra (Slovakia). The project leverages undervalued local resources, such as culture, food, human-animal bonds, and the environment, to promote Inclusive Health and Wellbeing (IHW) with a strong emphasis on gender, diversity, equity, and inclusion. It employs an integrated approach combining technological, digital, nature-based, cultural, and social innovations in specific urban public spaces with solutions co-designed, co-deployed, and co-managed in collaboration with local stakeholders.

One of its main outputs is the **IN-HABIT Data Platform** to assess the impact of Visionary and Integrated Solutions (VIS) solutions on mental health, socio-economic wellbeing and healthy lifestyles of people in the city areas of intervention. Conceptualised as a long-term sustainable resource, the platform secures open and consistent data by the integration, management and visualisation of data from various sources (sensors, cameras, open data, app) at the city level (i.e., air pollution and temperature, movements of individuals, bikes, and landscape features). It produces interactive scenarios, GIS mapping and spatial/environmental analysis in real-time.

The **platform** has been conceptualized to support three main objectives:

- To provide comprehensive visualisations of all data generated by the sensors, making it easier to interpret;
- to support research by generating real-time visualisations of key quantitative parameters, enabling immediate and precise monitoring; and
- to offer the option to download the collected data for further detailed analysis, enhancing researchers' ability to draw conclusions and develop evidence-based solutions.

Currently, the **IN-HABIT Data Platform** unifies real-time and historical data from diverse sources into a robust Big Data infrastructure. It supports analytics, smart planning, and optimal operations through an open, scalable ecosystem with a holistic interface. Special relevance is given to its automatisation feature for KPI analysis in a user-friendly dashboard, specifically designed for each of **IN-HABIT**'s pilot sites:

- **The Patios in Cordoba:** Traditional spaces (inner courtyards) that act as eco-social hubs in the urban spaces due to their environmental and socialisation functions.
- **The Food Market in Riga:** A food and environmental hub central to community life, blending traditional roots with an innovative business model.
- **The Animal Relational Areas in Lucca:** Outdoor areas fostering interactions between humans and animals, reflecting the city's appreciation for the unique bonds people share with their pets.

- **The Cycle Road in Nitra:** A key urban space connecting the city with an industrial district where users connect with nature and art through immersive activities and sensory experiences.

Given the advances achieved, the current Deliverable has been entirely reformulated and updated. Based on the project's objectives, outreach and pertinent observations provided by the reviewers during RP2, it describes the actual design, potential and expected results of the tool. The reconceptualisation of *Deliverable 7.6. IN-HABIT full operative Data Platform: Description of modules, sensors and data sources implemented in the four pilot areas* has been done by including the work performed by a company, GrayHats S.L., subcontracted by UCO, after the termination agreement of former partner Wellness Technology Group. The platform has been created by this company and adapted to the measurement objectives in each city and the overall project goals. This document presents the architecture, step by step, and portrays the platform from the backend to the frontend, as well as a detailed description of its full capabilities.

The **IN-HABIT Data Platform** is an ambitious tool open to consultations. It collects data on the influence on people's health and wellbeing derived from the contact with nature within their own cities and provides tailor-made measurements to foster analysis to produce informed decision-making in urban public spaces. Its **inclusive, impactful, and scalable** approach addresses health and wellbeing in our four European cities, sketching actionable to its replication in other locations as well as providing microdata to decision-makers and policymakers.

The **IN-HABIT Data Platform** is also fully aligned with the European Data Space approach. The **European Data Strategy** focuses on creating a unified data market where information can flow freely and remain interoperable across sectors and regions. Within this framework, the **IN-HABIT** platform prioritises standardised data models and collection methodologies, ensuring alignment with the strategy and enhancing the long-term usability and scalability of the collected data.

A **Data Space** is a decentralised ecosystem enabling secure data sharing, access, and usage among stakeholders while preserving privacy, privacy control, and sovereignty. Built on **interoperability, data standardisation, and trust,** it allows businesses, governments, and researchers to collaborate and derive value from shared data without compromising security or ownership.

The **IN-HABIT** platform can contribute significantly to the **EU's Data Space** by adhering to the **FAIR principles** (Findable, Accessible, Interoperable, and Reusable). The platform ensures data discoverability through indexing, accessibility via standard APIs, and compliance with schemas like **FIWARE** and **NGSI-LD.** By providing clear metadata and licensing conditions, it enhances data reusability for diverse applications in research, policymaking, and organisational use.

The integration of environmental, social and health data within the **IN-HABIT Data Platform** promotes cross-disciplinary research, driving innovative insights into public health, climate resilience, and social equity. This holistic approach aims to serve as a foundation for studies addressing urban wellbeing across Europe. Furthermore, standardised and aggregated data enables evidence-based policymaking, allowing authorities to address urban challenges such as air quality, climate change mitigation, relational patterns and accessibility while guiding funding and legislative decisions aligned with the broader EU agenda.

2. Strategic Conceptualisation of the IN-HABIT Data Platform and its Alignment with the Project

The **IN-HABIT Data Platform** is built entirely under a **measurement-driven approach**. One of its key objectives is to establish **shared conclusions** regarding improvements in the state of health and wellbeing across the four cities. To determine the **measurement variables (air quality, number of people, radiation level, soil conditions, and weather state),** the **IN-HABIT**’s core **objectives** were reviewed and considered as a coherent framework.

To **improve the health and wellbeing** of people in the four European cities, to **optimise the use and inclusivity of public spaces**, to **foster community engagement** in shaping solutions, to **leverage technology to create healthier**, more inclusive environments, some key variables were chosen per city linked to its focus and local engagement. The selection of devices was defined according to the topics to be measured by the local teams, so parameters obtained derive into usable data. The description of the spaces to be monitored in each city and the health and wellbeing spaces to be measured in each of them are described next. Tables displaying the number and type of devices per city, the relevance of the data collected, the impact on the space measured and its relationship with the overall **IN-HABIT** project are also included.

In **Cordoba**, sensors are installed in patios located in the historical centre. Patios have been part of Cordoba city for centuries. The combination of plants, water bodies, architectural features and wind circulation, act as a passive cooling system that reduces the urban heat island effect, lowers energy consumption and GHG emissions and increases thermal comfort. As green spaces, they also offer a range of ecosystem services, acting as green cells in the middle of the city. Patios are also spaces for socialisation and develop social activities in contact with nature. They represent a multifunctional solution to the challenges of urban living, blending environmental, social, and cultural benefits.

The **sensors in Cordoba** aim to measure how the different architectural, vegetation, and physical features of the patios influence their contribution to the mentioned health and wellbeing benefits. Data will contribute to identifying the most efficient patio designs in cooling down spaces, the most efficient plants in the use of water and reducing pollution, the capacity of CO_2 sequestration of different combinations of plant species and how the combination of different aspects can create synergies.

TABLE 1. DEVICES AND CONTRIBUTIONS TO THE STUDY OF HEALTH AND WELLBEING IN CORDOBA

Device		Cordoba			
		Monitored parameter	**Relevance of the data**	**Impact on the patio**	**Connecting with IN-HABIT Goals**
1	***Air Quality Sensor (EM500-CO2)***	PPM de CO2 Temperature Humidity Atmospheric pressure	Air quality is linked to respiratory health and overall well-being	It measures how vegetation and design affect CO_2 capture and thermal regulation	Identify natural solutions that improve urban environmental conditions
2	***Soil Temperature, Humidity and Conductivity Sensor (Dragino LSE01)***	Humidity Temperature Electrical conductivity (salinity) of the soil	Understand water retention and vegetation sustainability	Optimizes irrigation practices and ensures plant health under water stress	Supports efficient water management for environmental sustainability Identify the most efficient type of vegetation to cool down spaces
3	***PAR Radiation Sensor (Dragino WSS-07)***	Photosynthetically active radiation received by plants	Light is essential for photosynthesis and CO_2 capture	Evaluate light distribution and optimize design to maximize ecological contribution	It measures how patios act as urban microecosystems Identify the most efficient type of vegetation to cool down spaces
4	***Flowmeter (Qalcosonic Axiom W1)***	Water consumption in plant irrigation	Identifies patterns and proposes water efficiency strategies.	Evaluates the impact of interventions on reducing water consumption	Develop sustainable practices that optimize natural resources

In the **Āgenskalns Market in Riga**, sensors are installed across various key areas to monitor environmental quality and visitor dynamics, integrating technologies into a historic urban space. The CO2 sensors measure air quality, temperature, and humidity, ensuring food quality and safety, and a comfortable environment that promotes the well-being of neighborhood citizens. Meanwhile, the people counting camera provides data on visitor attendance patterns throughout specific days, weeks, and months, helping to analyze how different activities and seasons impact attendance.

This data-driven approach enables the **Āgenskalns Market** to understand the effects of **IN-HABIT** activities and their influence on community engagement and potential impact on visitors' well-being. Data reveals increased attendance during thematic events that incorporate the community kitchen, environmental enhancements, and waste reduction initiatives within the market space.

Table 2. Devices And Contributions To The Study Of Health And Wellbeing in Riga

Device		Riga			
		Monitored parameter	**Relevance of the data**	**Impact on market**	**Connecting with IN-HABIT Goals**
1	***Milesight EM500-CO2 LoRaWAN Carbon Dioxide Sensor (4 in 1)***	Carbon Dioxide (CO2) Temperature Humidity Barometric Pressure	Monitors environmental factors and ensures air quality and thermal comfort in public spaces	Enhances the market's food quality and safety and ensures a healthier and more comfortable space for visitors; it supports data-driven improvements, such as better ventilation and event planning	Provides data to evaluate the impact of market activities on the food quality and the local community's health and well-being, enabling evidence-based strategies to create healthier food access and more inclusive, sustainable, and engaging public spaces

Table 3. Devices And Contributions To The Study Of Health And Wellbeing In Riga (Cont.)

Device		Riga			
		Monitored parameter	**Relevance of the data**	**Impact on market**	**Connecting with IN-HABIT Goals**
2	***Hikvision DS-2CD6825G0/C-IS***	Number of people in the market	Assesses the effectiveness of activities, understanding local citizens' attendance, and optimizing space usage	Provides accurate insights into visitor flow, helps optimize event planning, resource allocation, and space management; it allows tracking the success of events, supporting a better visitor experience and fostering inclusivity	Provides data to measure the impact of cultural, social, and environmental interventions at the market, supports the project's focus on enhancing well-being and inclusivity by tracking how these activities influence visitor engagement and attendance patterns, evidence-based approach informs strategies to create more welcoming and health-promoting public spaces

In **Lucca** the monitoring system have some specificities related to the nature of some of the interventions. From a structural point of view, the organisation is based on two relational areas and 15 km of animal lanes organized in different paths according to the distance and the difficulties.

The monitoring system is devoted to count both the people frequenting the relational areas and the animal lanes in different stages and in different moments of the day and of the seasons with the goal to analyse the impact of activities and better understand usage patterns.

Table 4. Devices And Contributions To The Study Of Health And Wellbeing in Lucca

Device		Lucca			
		Monitored parameter	**Relevance of the data**	**Impact on public spaces**	**Connecting with Goals**
1	***PAX Counter***	Number of people	Density and patterns of space use	Identifies areas of high human-animal interaction and patterns	Design interventions to maximise shared use of spaces Information on use and socialisation patterns

In **Nitra** the pilot area is comprised of residential, industrial, and recreational spaces connected by the Nitra River and a bike path, several key locations are to be equipped with sensors. In two newly developed open green public spaces along the corridor (Picnic Meadow along the bike path on entry into residential neighbourhood **Dražovce and Picnic Meadow** in the Nitra River floodplain), sensor technology is deployed to monitor visitor patterns and support the enhancement of public spaces. People counting cameras are to be installed at key entry points to measure the entry and duration of visitors' stays, capturing data on how the meadow is utilised during different times and seasons. These insights are aligned with interventions such as tree and meadow planting, multifunctional reversible street furniture, terrain modulations to create flood-resistant play elements and public grills to encourage outdoor activities.

Similarly, outdoor cultural and community centre **Hidepark** employs a combination of people counting cameras and air quality sensors to integrate environmental and community-based monitoring. A people counting camera monitors the semi-public area, capturing data on entry patterns and space utilisation. Meanwhile, air quality sensors are proposed to monitor environmental factors in the community garden, such as particulate matter and CO2 levels, ensuring a healthy and vibrant atmosphere for gardening, workshops, and cultural events. By connecting sensor data with activities like green site-specific art installations, events in the community kitchen and the DIY café, the Hidepark location demonstrates how data-driven approaches can enhance urban spaces, improve environmental conditions, and support community engagement.

TABLE 5. DEVICES AND CONTRIBUTIONS TO THE STUDY OF HEALTH AND WELLBEING IN NITRA

Device		Nitra			
		Monitored parameter	**Relevance of the data**	**Impact on public spaces**	**Connecting with Goals**
1	***Air Quality Sensor (EM500-CO2)***	PPM CO2 Temperature Humidity Atmospheric pressure	Air quality is linked to respiratory health and overall well-being	It measures how people's flux and activities influence CO_2 rise and comfort	Determine the impact of organised activities and interventions on air quality, health benefits from spending time in green spaces and comfort

Table 6. Devices And Contributions To The Study Of Health And Wellbeing in Nitra (Cont.)

Device		Nitra			
		Monitored parameter	**Relevance of the data**	**Impact on public spaces**	**Connecting with Goals**
2	***People Counting Camera*** ***W128198529 Hikvision IDS-2CD7587G0-XZHSY (2.8-12MM)***	People in People out	The influx of people inside the area is related to the use of space	Identifies the time periods in which the use of space is most intensive	Determine the impact of organised activities on the influx of people; measure attendance and success of soft activities and impact of deployed hard solutions on space use
3	***PAX Counter***	Number of people in an area	Density and patterns of space use	Identifies the time periods and areas in which new public spaces use is most intensive	Provides measurement of the impact of new accessible green spaces on users' behaviour; their duration of stay in public green spaces, number of people congregating new green spaces

In general terms, all sensors feeding into the **IN-HABIT Data Platform** are guided by a forward-thinking approach, ensuring that the relevance of each parameter translates into meaningful impacts within the studied cities.

2.1 Additional parameters in the design of the platform

2.1.1.Improving environmental health and wellbeing

By monitoring **air quality in shared spaces**, the **IN-HABIT Data Platform** monitor the role of nature-based innovations, emphasising the importance of green spaces that improve air quality.

Key features include:

- **Real-Time Monitoring:** IoT air quality sensors can measure pollutants (e.g., PM2.5, CO2, NO2) in real-time across public spaces like community patios, parks, relational areas, or markets.
- **Localized Insights:** Data can reveal pollution hotspots, identify trends, and determine how urban activities (e.g., traffic, festivals) impact air quality.
- **Health Alerts:** Automated alerts can notify citizens, particularly vulnerable groups (e.g., children, elderly, and those with respiratory issues) when air quality is poor.
- **Sustainability Efforts:** Insights can guide policies to reduce emissions and promote pedestrian zones or green corridors.

2.1.2. Optimising the use and inclusiveness of public spaces

By **counting people in public spaces,** the **IN-HABIT Data Platform** patterns can be identified that support co-design and co-management by involving communities in tailoring public spaces to their needs. This data is very helpful to increase accessibility and equity, ensuring functional, welcoming spaces for diverse populations.

Key features include:

- Foot Traffic Analysis: IoT-enabled people counters can track the flow and density of visitors in parks, markets, or cultural venues.
- Behavioural Patterns: Data can identify peak usage times, underutilized space.
- Design Optimization: Insights can inform the design and deployment of inclusive amenities (e.g., seating, lighting, ramps).
- Social Distancing: In the context of public health crises (e.g., COVID-19), sensors can monitor crowding and assist in enforcing safety protocols.

2.1.3. Enhancing Wellbeing with Technology

By **leveraging technology to create healthier, more inclusive environments**, the **IN-HABIT Data Platform** combines technological and nature-based innovations for sustainable solutions. Ensures inclusivity by tailoring interventions to the needs of marginalized groups.

Key features include:

- **Stress-Free Environments:** Data from sensors can identify factors like noise pollution, overcrowding, or poor air quality that negatively impact mental health.
- **Green Space Enhancement:** Environmental sensors can evaluate the impact of urban greening projects on air quality, temperature regulation, and biodiversity.
- **Targeted Interventions:** IoT insights can help design interventions tailored to specific communities, addressing health disparities effectively.

2.1.4. Cross-City Comparisons

By **leveraging technology to create healthier, more inclusive environments**, the **IN-HABIT Data Platform** encourages a collaborative approach, aligning with the project's multi-city framework.

Key features include:

- **Standardized Metrics:** IoT platforms with interoperable standards allow cities to measure and compare indicators like air quality, foot traffic, or accessibility consistently.
- **Best Practices:** Analytics can highlight successful interventions in one city that could be adapted for another.
- **Collaborative Learning:** IoT-driven insights foster dialogue and collaboration between stakeholders in Cordoba, Riga, Lucca, and Nitra.

2.1.5. Enabling a Sustainable and Inclusive Future

By **creating a self-sustaining model for IHW improvements**, the **IN-HABIT Data Platform** combines technological, social, and cultural innovations to create a holistic framework for wellbeing.

Key features include:

- **Data for Policy:** Sensor data supports evidence-based policymaking to sustain health and wellbeing initiatives.
- **Cost-Effectiveness:** IoT's real-time monitoring reduces reliance on manual data collection, making solutions affordable for small and medium-sized cities.
- **Innovation Ecosystem:** APIs and open data promote third-party innovation, encouraging startups, NGOs, and academic institutions to build solutions aligned with **IN-HABIT** goals.

The **IN-HABIT Data Platform** settles a bridge between spaces and humans, collecting data *in situ* and delivering it through a common place where researchers, policymakers or stakeholders can know the state of the variables of their interest.

3. The IN-HABIT Data Platform Architecture

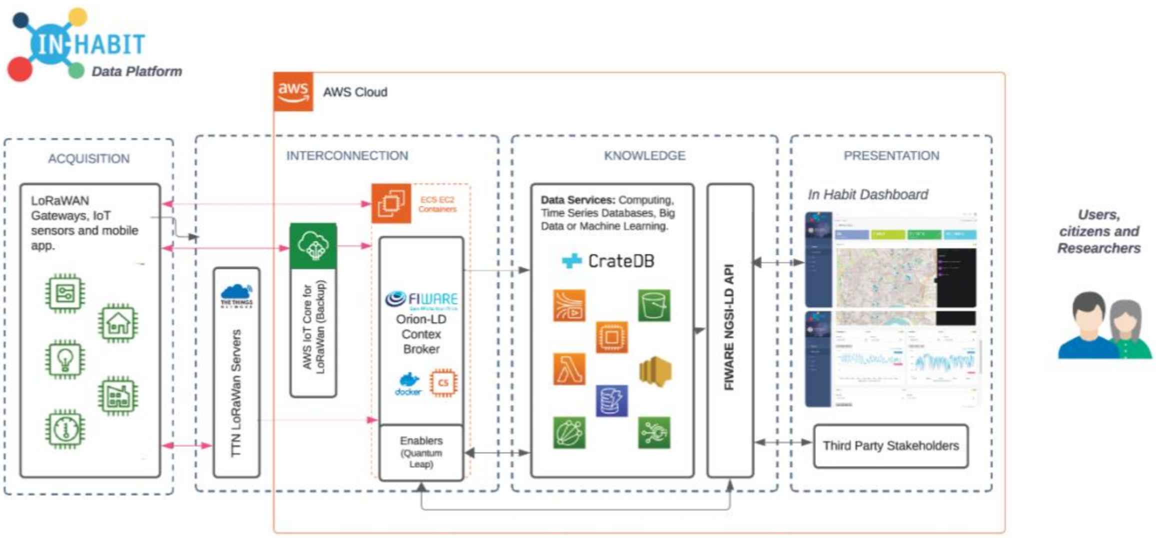
To improve **inclusive health and wellbeing** in small and medium-sized cities, the **IN-HABIT Data Platform is** designed to collect, process, analyse, and visualise data from settled variables that measure health and well-being through IoT devices and sensors. **Some of the key features offered by the Platform are:**

1. **Data Collection and Ingestion:**
   - Integration with diverse IoT devices (e.g., air quality monitors, wearables, health kiosks, mobility aids).
   - Support for multiple protocols (e.g., MQTT, LoRaWAN, HTTP, and Bluetooth) for flexibility in device connectivity.
2. **Real-Time Data Processing:**
   - Capabilities for processing real-time data streams to detect anomalies or trigger alerts (e.g., air pollution thresholds, irregular health patterns in wearable devices, etc.).
3. **Data Analytics and Insights:**
   - Tools for analysing trends in public health and environmental conditions.
   - Enables predictive analytics to forecast the use of public facilities.
4. **Interoperability:**
   - Compliance with open standards (e.g., NGSI-LD for context information management) to ensure seamless integration with other city services and platforms.
5. **Scalability and Flexibility:**
   - Designed to scale with the city's population and infrastructure growth.
   - Modular architecture to accommodate new devices, data sources, or use cases.
6. **User-Centric Services:**
   - Accessible dashboards for city officials, healthcare providers, and citizens.
   - APIs for external developers to build applications enhancing community health and inclusivity.

7. **Data Privacy and Security:**
    - Robust mechanisms for anonymizing sensitive health data.
    - No personal health information is stored on the platform.
    - Compliance with data protection regulations (e.g., GDPR, HIPAA).
8. **Affordability:**
    - Leverages open-source solutions and cost-efficient technologies to suit the budget of smaller cities.

The next diagram depicts the platform's general architecture:

IMAGE 1. ARCHITECTURE IN-HABIT DATA PLATFORM



3.1. Key Foundational Components

3.1.1. Cloud Infrastructure (AWS)

AWS (Amazon Web Services) is a leading cloud infrastructure provider offering a comprehensive suite of services for computing, storage, networking, and analytics, among other functionalities. It supports organizations in building, deploying, and scaling applications and services. AWS is known for its **global infrastructure**, robust **security protocols**, and extensive **ecosystem** of tools and services tailored to various use cases. AWS can handle massive amounts of IoT data generated by sensors, devices, and applications in a city and offers on-demand scalability, enabling the Platform to adjust resources dynamically as their infrastructure evolves.

For the **IN-HABIT Data Platform**, AWS provides several essential services, including:

- **EC2 (Elastic Compute Cloud)**: Scalable virtual machines for running city-wide applications.
- **Lambda**: Serverless computing for real-time event-driven IoT processing and middleware functions.
- **S3 (Simple Storage Service)**: Scalable and durable object storage for data from sensors and devices.
- **Data Analytics and Machine Learning**: Services such as SageMaker, Amazon Kinesis or Redshift as OLAP database for data analytics.
- **VPC (Virtual Private Cloud)**: Isolated cloud resources for secure communication.
- **IAM (Identity and Access Management)**: Fine-grained access control for sensitive smart city data.

3.1.2. The Things Network (TTN)

The **Things Network (TTN)** is a global, open-source platform for deploying and managing LoRaWAN (Long Range Wide Area Network) networks. It provides tools and infrastructure for securely connecting IoT devices to the internet using LoRaWAN, a low-power, long-range wireless protocol ideal for IoT applications.

TTN enables communities, businesses, and cities to build and maintain IoT solutions with minimal costs, emphasizing **openness**, **collaboration**, and **sustainability**, and enables data transmission over distances up to 15-20 km in rural areas and 2-5 km in urban environments. TTN relies on gateways installed by individuals, organizations, and communities. This collaborative approach ensures broad coverage without relying solely on project resources or commercial telecom providers.

Security features include device authentication, data encryption, and secure key management. Offers APIs and integration with platforms like **AWS**, **Microsoft Azure**, and **FIWARE** for advanced analytics and processing.

3.1.3. FIWARE Technology Stack

FIWARE was originally promoted by the **European Union** through a public-private partnership program called the **Future Internet Public-Private Partnership (FI-PPP)**. This initiative aimed to advance Europe's technological leadership in building a framework for the **Future Internet**. It was jointly funded by the European Commission and several private companies, research organizations, and academic institutions.

This technology is particularly valued for its open, non-proprietary approach. It eliminates dependency on specific vendors, making it attractive for public administrations and businesses aiming to adopt sustainable and flexible solutions. Its ability to support diverse domains and its adherence to global standards like NGSI-LD have made it a popular choice in digital transformation projects.

In the context of IN-HABIT it offers:

1. **Context Information Management**: At the heart of FIWARE is its **NGSI-LD API**, a standard for managing context data in real-time. It allows applications to gather, process, and share information about the state of various entities (e.g., sensors, devices, buildings).
2. **IoT Integration**: FIWARE supports integration with Internet of Things (IoT) devices, enabling seamless data collection from sensors, actuators, and other devices.
3. **Open Data**: FIWARE is often used to publish and consume open data, fostering transparency and innovation in public and private sectors.
4. **Interoperability**: By adhering to open standards, FIWARE ensures that its applications can interoperate with other systems, reducing development overhead and improving scalability.
5. **Marketplace of Generic Enablers**: FIWARE offers a range of **Generic Enablers (GEs)** modular, reusable software components that provide functionalities like data processing, storage, analytics, and user interfaces.
6. **Ecosystem Support**: FIWARE is supported by an active community of developers, businesses, and public entities. It also fosters innovation through collaboration and provides certification programs to ensure compliance with its standards.

3.1.4. FIWARE Smart Models

FIWARE Smart Models are standardized, open-source data models designed to enable seamless interoperability in smart solutions. These models define how to represent and exchange data across diverse systems, ensuring a common language for various domains like smart cities, energy, agriculture, and more.

Smart **Models** are part of the **FIWARE ecosystem**, which aims to foster open standards for smart city technologies. They are based on **NGSI-LD**, a standard API and data format for context information management.

FIWARE Smart Models provide a common framework to represent data, allowing diverse systems (e.g., IoT devices, analytics platforms, and public services) to communicate effectively. By using open and standardized data models, data, insights, and entities are not tied to proprietary systems. It fosters competition, reduces costs, and enables integration with new technologies.

Well-structured, standardized data improves the effectiveness of machine learning models and analytics, leading to better insights and decision-making. FIWARE Smart Models align with global initiatives such as the **European Data Spaces** and the **UN Sustainable Development Goals (SDGs)**, ensuring relevance and compliance with international benchmarks.

3.1.5. FIWARE Service Interface (NGSI-LD API)

NGSI-LD (Next Generation Service Interface - Linked Data) is an open, standardized API and data model specification designed for managing **context information** in a dynamic and scalable way. NGSI-LD defines a common structure for representing and sharing data across systems. NGSI-LD's semantic capabilities facilitate the integration of data from these domains into a unified ecosystem. It is a core component of the **FIWARE ecosystem** and a key enabler of interoperability for smart city projects and other domains like agriculture, energy, and industry.

NGSI-LD builds upon the earlier NGSI specifications but introduces **Linked Data Principles**, enabling richer data interconnections and semantic interoperability. It is maintained by **ETSI** (European Telecommunications Standards Institute) as part of its efforts to foster global IoT and smart city standards.

For the **IN-HABIT Data Platform** it provides a RESTful API for operations such as creating, updating, querying, and subscribing to context information. The API supports real-time data streams and the integration of historical context for analytics and predictions.

3.1.6. Quantum Leap and Crate DB

Quantum Leap is a FIWARE Generic Enabler that acts as a time-series aggregator for IoT and context data managed through the **NGSI-LD** interface. It is designed to store and query time-series data in a scalable and efficient way, enabling advanced analytics and visualization of historical context information. It transforms context information updates into time-series that reflects the evolution of entity attributes over time, enabling trend analysis.

CrateDB is an open-source, distributed SQL database designed for handling machine data and time-series data. It is highly optimized for scenarios involving real-time data ingestion, storage, and querying, making it a perfect match for Quantum Leap in IoT deployments.

This database is well-suited for certain types of **big data analytics** and **machine learning** training processes, especially when dealing with machine-generated data, time-series data, or real-time processing needs. However, its suitability depends on the specific requirements of the use case.

Quantum Leap subscribes to context data updates from IoT sensors via the FIWARE Context Broker and stores it in CrateDB.

3.1.7. Docker Containers

Docker is an open-source platform that uses **containerization** to enable developers to build, package, and run applications in isolated environments called **containers**. Containers encapsulate an application and its dependencies, ensuring consistency across various computing environments.

Unlike traditional virtualization, where entire operating systems are replicated, Docker containers share the host OS kernel, making them lightweight, portable, and efficient. These containers run consistently across different environments, whether it's a developer's laptop, an on-premises server, or a cloud platform.

Docker containers ensure that applications built by different stakeholders (vendors, public agencies, startups) can run seamlessly on any infrastructure, avoiding infrastructure vendor locking and maximizing the portability of the platform.

3.1.8. UNE 178 104 Standard

The **UNE 178104** standard, titled *"Smart Cities - A Standard for City Platforms,"* is a Spanish national standard developed by **AENOR (Asociación Española de Normalización)**. It provides guidelines and specifications for the development, implementation, and management of city platforms within the context of smart cities.

Some key aspects offered by UNE 178104 in the context of the IN-HABIT Data Platform are:

1. **Purpose**: The standard aims to define the functional and technical requirements for city platforms that integrate and manage services, applications, and data within a smart city ecosystem. It promotes interoperability, scalability, and sustainability to improve urban management and citizen services.
2. **City Platform Role**: A city platform is a technological infrastructure that consolidates data from various sources (e.g., IoT sensors, public services, private entities) to facilitate decision-making and service delivery.
3. **Core Principles**:
    a. **Interoperability**: Ensures compatibility with existing and future systems using open standards and APIs.
    b. **Data Management**: Provides frameworks for collecting, processing, storing, and sharing data securely and efficiently.
    c. **Modularity and Scalability**: Allows cities to expand their platform functionalities as their needs grow.
    d. **Open Standards**: Encourages the use of open technologies to avoid vendor lock-in.
    e. **Citizen-Centric Approach**: Focuses on improving quality of life and enhancing public services for residents.
4. **Key Functional Areas**:
    a. **Data Integration**: Tools for consolidating and standardizing data from multiple city systems.
    b. **Service Management**: Mechanisms to coordinate urban services (e.g., traffic, energy, waste management).
    c. **Security and Privacy**: Protocols to protect sensitive information and ensure compliance with data protection regulations like GDPR.
    d. **Monitoring and Analytics**: Real-time and historical data analytics for informed decision-making.

5. **Alignment with Other Standards**: UNE 178104 aligns with broader international frameworks, including those from **ISO** and **ITU**, ensuring its relevance beyond Spain. It also integrates with complementary standards in the UNE 178 series, which focus on various aspects of smart city development.

3.2. Harmonizing Health and Wellbeing Metrics Across Four Cities: The Layers

3.2.1. The Data Acquisition Layer

The **Data Acquisition Layer** in the **UNE 178104 standard** refers to the component of the platform responsible for collecting data from various sources within the project scope: the sensors, installation and locations. This layer serves as the entry point for raw data and ensures its seamless integration into the platform. Here we will be acquiring data from different sources, IoT sensors, CCTV cameras or public APIs, as well as LoRaWAN Gateways.

For each city, devices were carefully selected to measure variables aligned with their specific knowledge objectives, as is represented in the following table:

TABLE 7. DATA ACQUISITION NETWORK: CITIES, SITES AND SENSORS

City	Site Denomination	Type of Sensor					
		Soil	Par Radiation	CO2 Air Quality	Flowmeter	People Counter(s)	Weather Station
Cordoba	*Patio*	*	*	*	*	-	*
Lucca	*Dog Park*	-	-	-	-	*	-
Riga	*Market*	-	-	*	-	*	-
Nitra	*Cycle Road*	-	-	*	-	*	-

In Cordoba, most of the sensors had been previously installed by WTG. However, due to exposure to varying weather conditions, from extreme heat to cold, many sensors experienced frequent damage. An inventory was conducted to assess the condition of the remaining sensors. In the summer of 2024, a new batch of sensors was deployed and integrated into the common FIWARE system to ensure connectivity. The following sections present the network of sensors and their alignment with the specific metric objectives of each city.

3.2.1. Cordoba: Health and Wellbeing around Culture and Heritage

The **IN-HABIT** project in Cordoba centres around the traditional Patios that are considered UNESCO Heritage. Patios are analysed as focal points to study their role as passive cooling systems that enhance health and wellbeing and mitigate heat island effect. Patios are monitored to study how different parameters influence temperature drop due to measurable factors such as CO2, irrigation, sun radiation, and soil attributes. Patios will also be traced to increase water efficiency.

These measures directly benefit residents by **creating cooler, healthier and more comfortable spaces for social interaction, relaxation, and community bonding**. Improved environmental conditions in the patios can lower energy consumption by reducing the need for air conditioning. The insights gained from this monitoring will guide urban planning, preserving their cultural and ecological value while making them models for climate-resilient urban living.

To analyse the patios, a microclimatic model was created to prototype a 'typical patio,' which elements generate a specific environment under equivalent meteorological conditions considering each ideal parameter by plant and species.

To establish the model, **two sets of variables were considered**, enabling the efficient study of a **sample of 24 patios** and their subsequent classification into **six categories**:

a) Percentage of inert material cover (permeable/impermeable soils):

- Tiled floor/pavement/non-permeable floor.
- Porous and permeable planters/pavements.
- Dirt flooring, bowling, porous and permeable gardens/pavements.

b) Percentage of vegetation cover:

- No vegetation.
- Unrooted vegetation.
- Rooted vegetation.

In the study of the patios' contributions, other architectural features, as well as the profile of the residents, were considered to **enhancing thermal comfort and well-being. Devices were carefully selected to measure:**

- **Temperature and Humidity**. Monitored in real-time to allow evaluation of the cooling effects of various vegetation types and architectural features. This data helps optimise patio design to provide greater thermal comfort during extreme summer heat, reducing heat stress for residents, but also the thermal inertia that the patios can provide and how they can be affordable and efficient passive cooling systems.

- **CO_2 levels**. To provide insights into how effectively vegetation in the patios captures carbon, improving air quality and creating healthier living environments.
- **Photosynthetically Active Radiation (PAR).** To help determine how efficiently plants in the patios photosynthesize, guiding the selection of plant species that thrive under Cordoba's intense sunlight while contributing to cooling and air purification.

When promoting **sustainable water use**, devices deliver metrics of:

- **Water flow**. To enable efficient irrigation practices by preventing overuse and ensuring optimal watering schedules. This not only conserves water but also maintains healthy vegetation critical for cooling and shading. It also will permit the identification of the species that, with the minimum watering, provide the best results.
- **Soil moisture levels**. To ensure that plants are neither overwatered nor under-watered, supporting their health and longevity. Conductivity measurements help optimize the use of nutrients, ensuring lush and effective vegetation growth.

The Devices

- **Dragino LSE01: LoRaWAN Soil Moisture & EC Sensor.**

The Dragino LSE01 is a wireless sensor designed for agricultural uses. It enables real-time monitoring of soil conditions, helping farmers optimize irrigation, and crop management. Some key features include:

- ***Dual measurements*:**
  - Soil Moisture Probe: Measures the water content in the soil.
  - EC Probe: Detects the soil's electrical conductivity, indication salinity levels.
- ***Wireless Connectivity:*** Operates via LoRaWAN, ensuring long-range communication and minimal power consumption.
- ***Accurate and Reliable Data*:** Gives precise measurements for informed, data-driven decision-making.
- ***Easy Installation*:** Two probes are inserted into the soil for consistent monitoring.

PHOTO 1. SOIL MOSTURE & EC SENSOR

- **Device for PAR Radiation Measurement.**
  The PAR (Photosynthetically Active Radiation) sensor measures light energy within the visible spectrum (400-700 nanometers), which is critical for photosynthesis. This wavelength is the most effective when supporting plant growth. Some key features include:
    - Detects the intensity of light absorbed by plants, ensuring optimal light conditions for growth.
    - *Wide Applications*:
        - Monitors light exposure to optimize plant growth.
        - Studies the effects of light levels on ecosystems.
        - Assesses the impact of the environment and human activity on plant growth.
    - *Data Collection:* Gives accurate measurements of the intensity and duration of light exposure over a given area.
    - *Environmental Impact Analysis:* Support research on how light conditions affect ecosystems and plant development.

PHOTO 2. PAR RADIATION, ROOF

- **Air CO2 Sensor (EM500 Series).**
  The EM500 is a versatile sensor primarily designed for outdoor environments, offering a range of communications options. Some key features include:
    - *Battery-Powered:* Ensures long-lasting operation without frequent maintenance.
    - *Flexible Mounting:* Designed for various installation methods and needs.

PHOTO 3. AIR QUALITY. PATIO 22 GROUND FLOOR

PHOTO 4. AIR QUALITY. PATIO 22 FIRST FLOOR

- *NFC (Near Field Communication) Capability:* Enables easy configuration using a smartphone or PC software.
- *Data Monitoring:* Users have access to sensor data and track trends via the Milesight IoT Cloud platform.

- **Device for Water Flow: Flowmeter.**
  A flowmeter (also called a flow sensor or flow gauge) is a device designed to measure the rate of fluid flow within a pipe or closed conduct. Some key features and applications include:
  - *Accurate Water Flow Measurement:* Tracks the rate and volume of water flowing through irrigation systems. Ensures precise water delivery, optimizing plant health.
  - *Irrigation Optimization:* Helps prevent water waste by monitoring flow rates and adjusting irrigation as needed. Ensures uniform water distribution, reducing over/under watering.
  - *Leak Detection:* Identifies leaks in irrigation systems, minimising water loss. Prevents plant damage by maintaining a consistent water supply.

PHOTO 5. FLOW METER INSTALLED AT THE PATIO HYDRANT 22

- **Weather Station**
  The function of the weather station is **to compare** the data obtained from the sensors. It is located on the roof of a University of Cordoba building on Alfonso XIII Street, in the Historical Centre of the city. The reference measurements are based on the results produced by this device.

- **The Antennas.**
  The Electronics and IoT team installed advanced sensors in **24 patios to monitor key variables such as temperature, humidity, CO2 levels, PAR radiation, soil conductivity, soil moisture, and water usage in irrigation systems.** To make sure the data flows smoothly to the central platform, LoRaWAN antennas were carefully placed to ensure strong and reliable connectivity.
  The team tackled some challenges, including ensuring network coverage in densely built urban areas and adapting to the unique conditions of each patio. The equipment used was selected to perform in all conditions, with robust enclosures that provide full weather protection and built-in electrical safeguards to keep everything running smoothly.

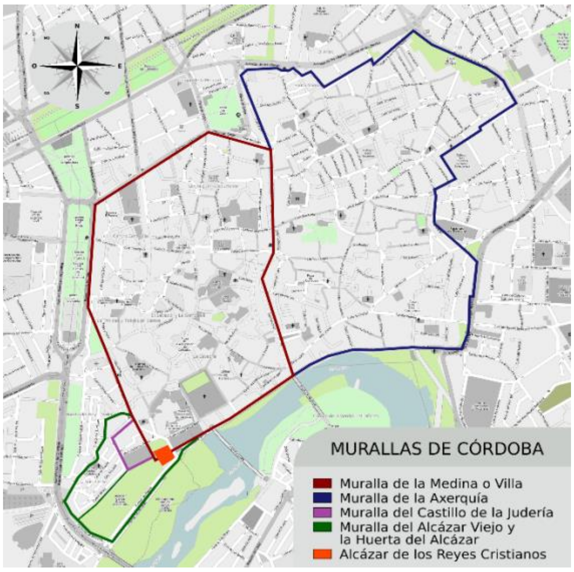
PHOTO 7. GATEWAY BOX LOCATED AT ORIVE PALACE

PHOTO 6. GATEWAY ANTENNA LOCATED ON THE ORIVE PALACE

The Location

Twenty-four patios were selected in the Axerquia neighbourhood. This is a historic district of Cordoba located in the centre of the city. These patios were chosen to represent the 4 patio typologies of the study and to be distributed as evenly as possible throughout the historic quarter, as well as the LoRaWAN gateways that collect the information.

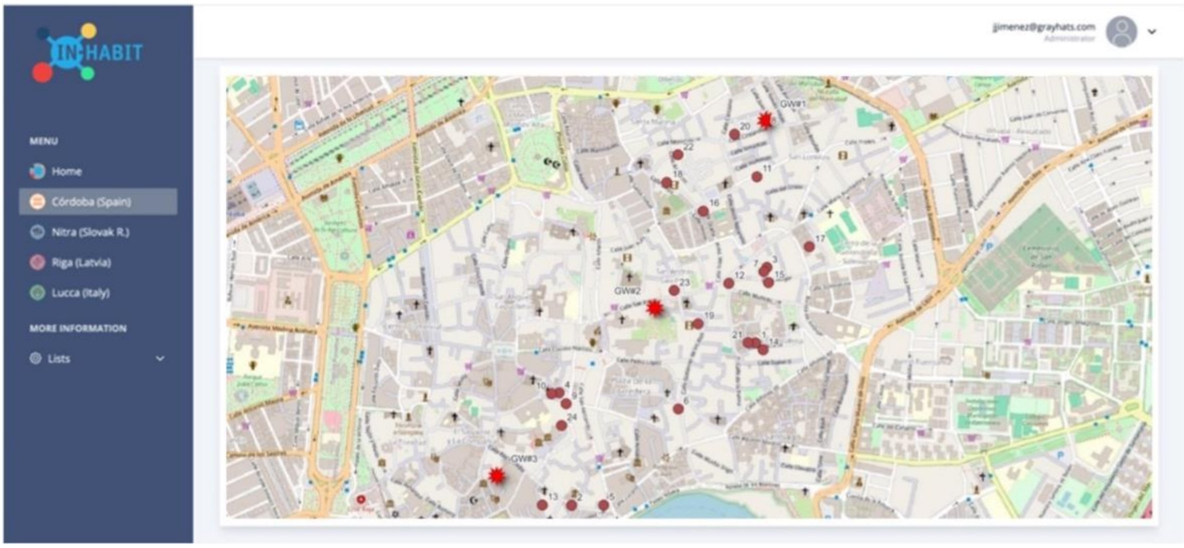
MAP 1. LA AXARQUIA NEIGHBOURHOOD, CORDOBA



The Installation

From the basic set of sensors, consisting of air quality, soil, irrigation water consumption and available radiation, the subset that fits the architecture was installed in each of the 24 patios of the Axarquia neighbourhood.

IMAGE 2. LOCATION OF THE PATIOS AND GATEWAYS IN THE HISTORIC CENTRE OF CORDOBA



Data was obtained and then introduced to the platform following the matrix of collecting information:

TABLE 8. EXAMPLE OF THE WORKSHEET COLLECTED BY THE LOCAL TEAM FROM EACH PATIO TO COMPLETE THE SENSOR COLLECTED INFORMATION

PATIO 1 (A1-B1)		
ADDRESS	Street, X	
COORDINATES	Latitude, Longitude	
USE OF THE BUILDING	Detached house-courtyard	
USER TYPE	Family X members	
PATIO GEOMETRY	Square 6.4 x 6.8m	
Nº FLOORS	Ground floor+1	
PLOT AREA	186 m2	
SUPERFICIE PATIO	44 m2	
% SURFACE	19,10%	
FLOOR	A1: > 80%	
% POROSITY	0%	
% VEGETATION COVER	B1	
VEGETATION	Rooted in the floor	
SHADE DEVICE	Yes	Awning
PRESENCE OF WATER	Yes	Pool (in use)
TYPE OF IRRIGATION	Dripping	

3.2.2. *Riga: Health and Wellbeing around food and environment*

In Riga the project's objective is to establish a multifunctional food hub for sustainably produced and locally sourced food around a local market (Nometņu Street 64, Āgenskalna). It will also function as a recreational and educational space with the integration of a range of activities devoted to different ages and social groups. The following data is obtained: **number of people accessing the internal and the external market, CO2 levels and temperature and humidity.**

The focus on environmental comfort, health, and inclusivity makes the market not just a centre for local food but also a hub for community interaction, education, and recreation, fostering well-being in Riga's diverse population.

To enhance visitor experience and comfort, devices were featured to:

- **Track the number of visitors** to the internal and external market areas helps identify peak usage times and patterns. This data informs strategies for crowd management, ensuring a comfortable and safe environment for all age groups and social demographics.

- **Understand foot traffic** to support the placement of educational and recreational activities, like therapy gardens and playgrounds, to maximize their accessibility and impact.
- **Monitor CO_2 concentrations** to provide insights into indoor air quality, especially in enclosed spaces within the market. Maintaining healthy air quality is crucial for creating a welcoming and safe environment for visitors.

Environmental data also supports the preservation of locally sourced and sustainably produced food, ensuring its quality while reducing waste. The **promotion of energy efficiency (sustainability) is sought** by data from environmental sensors that help to optimize energy usage for lighting, heating, or cooling. **Inclusivity** by tailoring spaces to be more comfortable and accessible based on the data, the market becomes a space that welcomes individuals of all ages and backgrounds.

The Devices

- **Air CO2 Sensor (EM500 Series) (See 3.2.1.1).**

As part of the **IN-HABIT** project's efforts to enhance quality of life and urban well-being, **nine EM500-CO2 sensors** have been installed at the Riga Market to monitor air quality and environmental conditions in real time. These sensors measure essential parameters, including **CO_2 concentration, temperature, humidity, and air pressure**, helping to identify areas with poor ventilation, excessive heat, or suboptimal air quality. By collecting and analysing this data, the project aims to implement more effective design and management strategies that foster a healthier, more comfortable, and sustainable environment for both visitors and the wider community.

- **People Counting System.**

The IP camera is designed to detect and count specific elements (e.g., people, vehicles) crossing designated areas by defining a series of virtual segments. These segments, when crossed in a specific direction or trigger the detection process, enable accurate tracking and counting within the camera's coverage area. Some key features include:

PHOTO 8. IP CAMERA. SAMPLE

  - *Non-Intrusive Monitoring:* The system operated without recording or storing any personal or sensitive data on the installed equipment, which ensures privacy compliance.

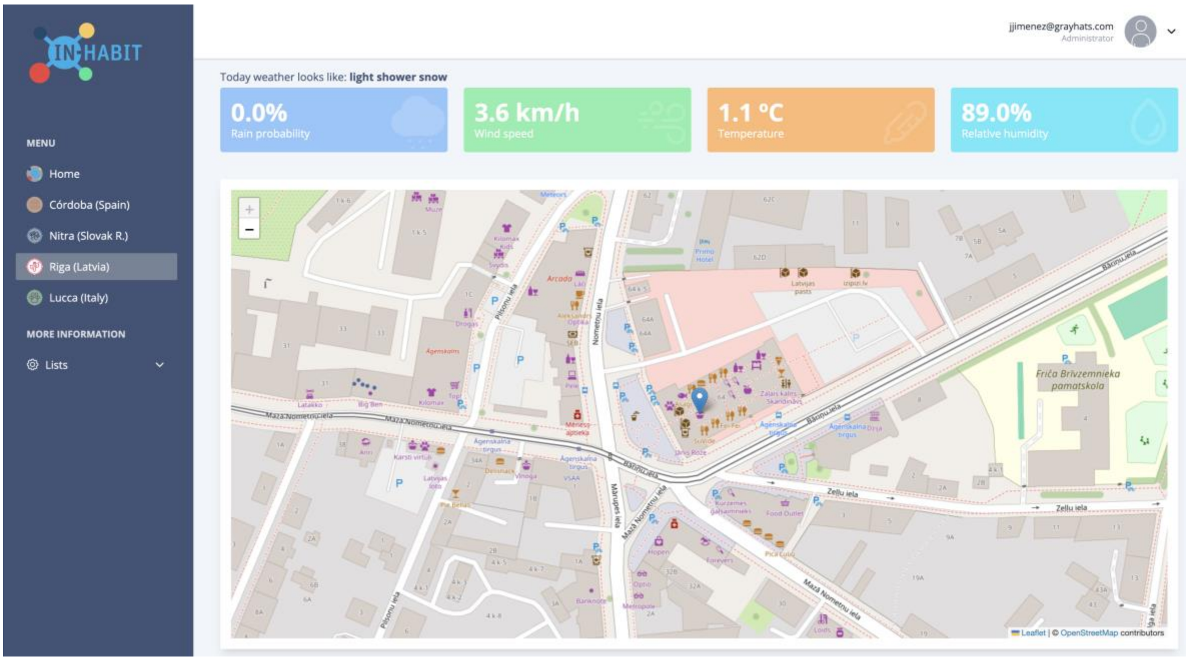
- *Versatile Detection:* Configurable to count different types of elements, such as people or vehicles.

In this specific case, some considerations were to be considered:

1. **Device:** Selection of the appropriate IP camera.
2. **Power Supply:** Ensuring reliable power sources for continuous operations.
3. **Installation Point:** Strategically positioning the camera for optimal coverage and accurate detection (See Image 2).
4. **Communications:** Establishing a stable network connection for data transmission and real-time monitoring.

The Location

MAP 2. RIGA'S MARKET. SENSOR LOCATION



The Installation

In the case of the local market in Riga the installation was performed on the inside and on the outside of it as the map depicts:

IMAGE 3. INDOOR DEVICE POINTS. ACCESSES

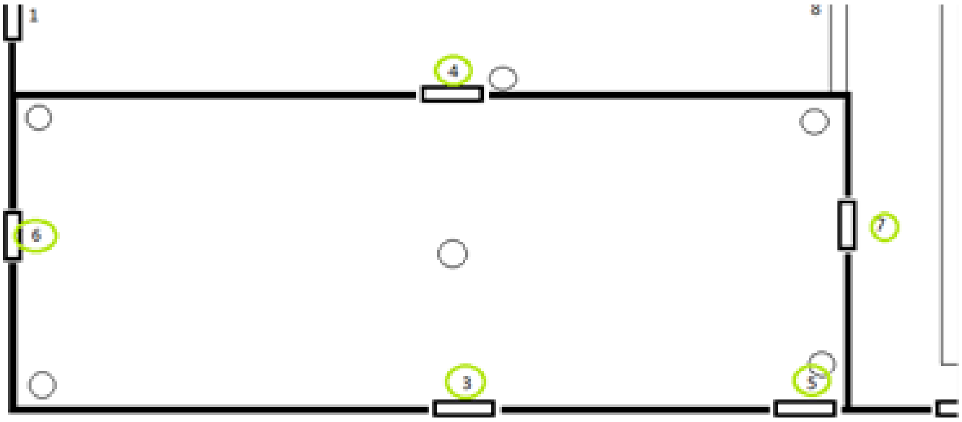


PHOTO 9. INDOOR DEVICE. Co2 SENSOR, 1

PHOTO 10. INDOOR DEVICE. Co2 SENSOR, 2

PHOTO 11. INDOOR DEVICE. PEOPLE COUNTING SENSOR

IMAGE 4. OUTDOOR DEVICE POINTS

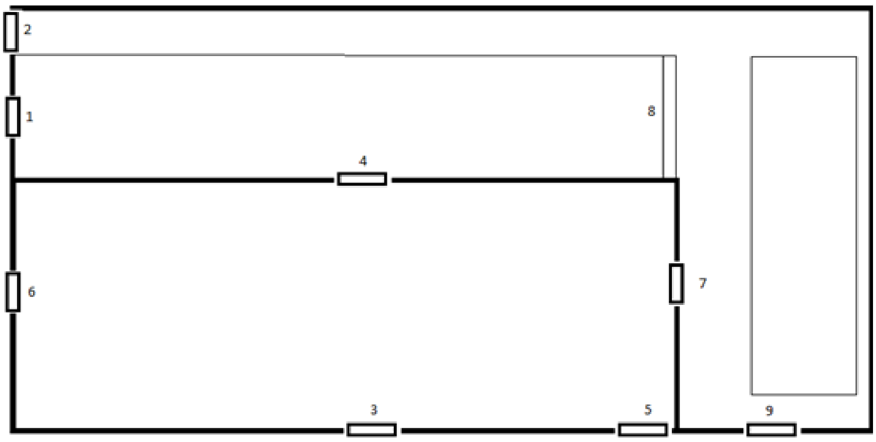


PHOTO 12. OUTDOOR DEVICE POINTS BY THE MAIN GATE, POINT 8

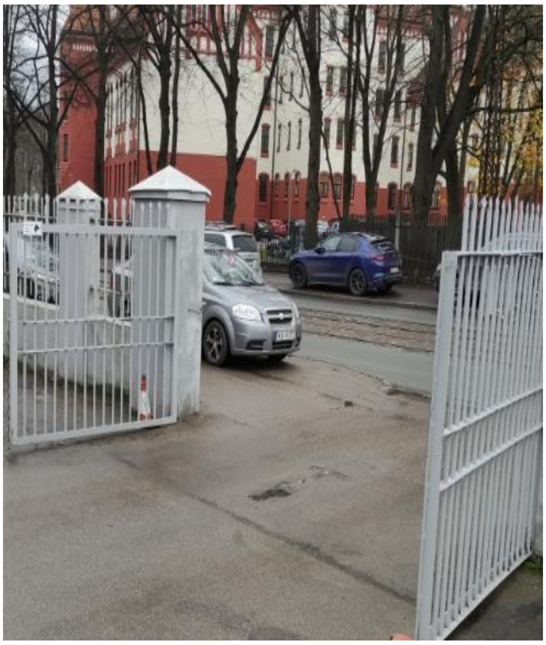


PHOTO 13. OUTDOOR DEVICE POINTS BY THE PARKING, POINT 9

3.2.3. Lucca: Health and Wellbeing around the interactions among human and animals

In Lucca the project defines the number of daily visitors involved in an area used for pet walking, regularly identified as animal relational areas. These areas have been designed to foster human-animal bonding and integrate nature-based solutions to improve social well-being and community cohesion. Lucca, known for its pet-friendly characteristics, has been a laboratory to explore how human-animal relationships can be transformed into innovative solutions that foster social inclusion and well-being.

Sensors have been deployed to collect relevant data to inform the impact of these interventions on the city. By tracking the number of visitors throughout the day, these sensors **enhancing citizen well-being through data insights providing information on** how effectively these spaces are being utilized and how they contribute to community cohesion and social inclusion. They:

- **Optimise space design and functionality:** The data collected helps identify peak usage times, indicating when these areas are most needed and valued by the community. Also, understanding patterns of use allows for improvements in the design and layout of these spaces, ensuring they are accessible, comfortable, and functional for both humans and animals.
- **Evaluate the effectiveness of interventions:** Monitoring visitor numbers helps assess the impact of nature-based solutions, such as green spaces and animal-friendly facilities, on social interaction and community well-being. The data can reveal trends, such as increased visitation after specific enhancements, providing evidence of their success.
- **Promote social inclusion:** The sensors help track how often these areas are used by diverse groups, supporting strategies to make them more inclusive for different demographics, including families, the elderly, and individuals with pets.
- **Support policy and decision-making:** Policymakers can use the insights to allocate resources effectively, such as scheduling maintenance or organizing activities during high-traffic periods. The data can also guide future investments in creating or expanding relational areas to meet community needs.

By ensuring that relational areas are well-utilized and continuously improved, these interventions foster stronger community ties, encourage outdoor activities, and promote interactions that enhance emotional well-being. The integration of human-animal bonding contributes to reducing stress, increasing happiness, and fostering a sense of belonging, making Lucca a model city for inclusive and sustainable urban living, i**mpacting positively on the community well-being.**

The Devices

In Lucca, sensors have been installed at strategic points, parks, recreation areas and areas with high pet traffic. The IoT team has completed setup and installation to ensure continuous data collection that feeds analytics into the data platform.

- **People Counting System.**

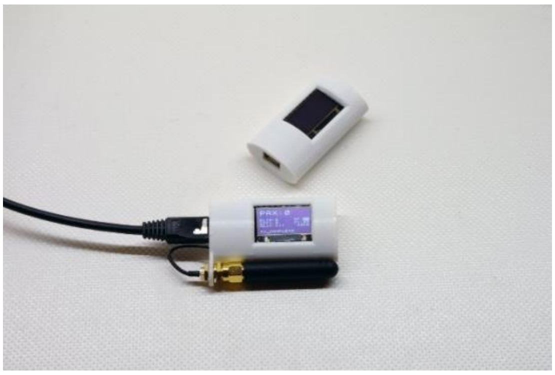


PHOTO 14. PEOPLE COUNTING DEVICE

The **People Counting System** used in Lucca is a lightweight and compact device that allows the flow of people to be measured in a discreet and efficient way. It is designed to transmit data using LoRa technology, which ensures long-range wireless communication and low power consumption. It is also powered by a 9W solar panel, the energy production of which has been previously evaluated to confirm that it is sufficient to keep the system running autonomously. Due to this configuration, the PAX Counter can operate sustainably and continuously without the need for complex electrical connections or frequent maintenance, facilitating its integration into urban environments.

PAX Counter devices have been installed in each relationship area, two in each, for both large and small dogs. These devices allow non-intrusive quantification of the flow of people, measuring the number of visitors by detecting signals emitted by mobile devices. In this way, the PAX Counter provides objective data on the intensity of use, time variations and social dynamics of the space, providing valuable information for the design, management and continuous improvement of these urban environments aimed at well-being and coexistence.

Image 5. Power Supply Using The 9W Solar Panel With A 3.7V 10000mAh Battery. 1

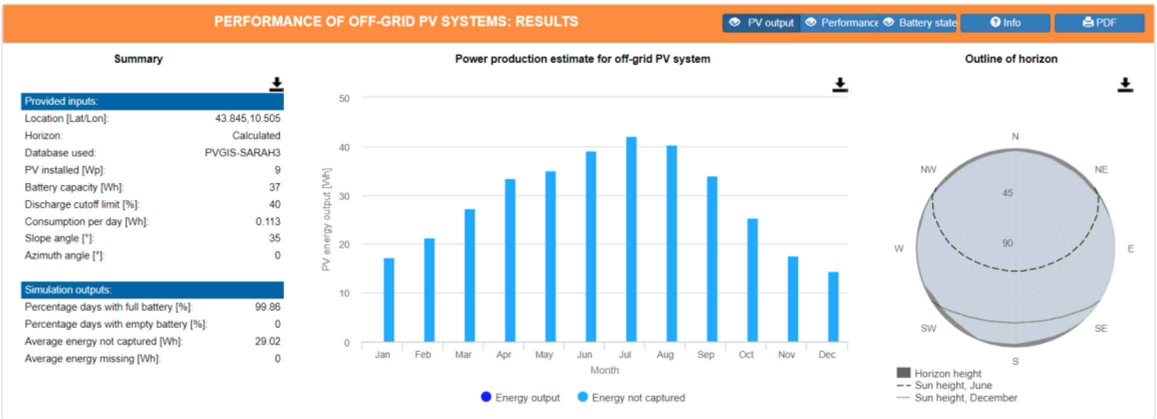


Image 6. Power Supply Using The 9W Solar Panel With A 3.7V 10000mAh Battery. 2

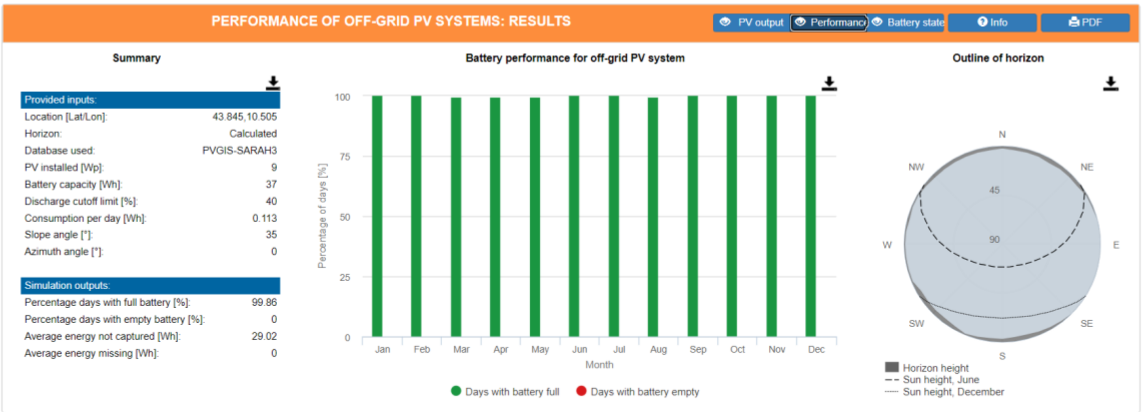
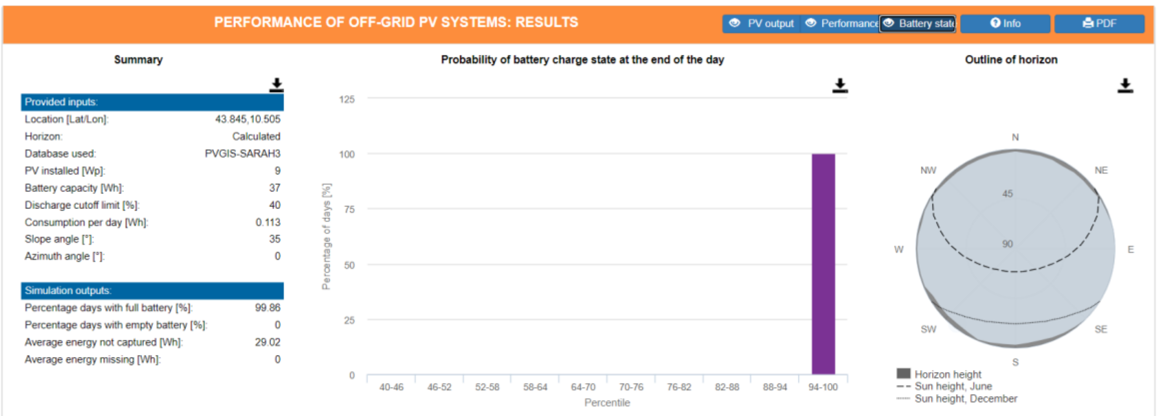


Image 7. Power Supply Using The 9W Solar Panel With A 3.7V 10000mAh Battery. 3



The Location

In Lucca, sensors have been strategically installed in parks, recreational areas, and zones with high pet activity. The IoT team has finalized their setup and installation, ensuring uninterrupted data collection to support analytics on the **IN-HABIT Data Platform**. The selected areas are:

- **Área Relazionale Campo di Marte** (GPS Location: 43.852058909757055, 10.521864597748467).

  At the request of the local team, the system is positioned as far as possible from the car park to reduce interference and to optimize data quality. Devices are placed near the houses that delimit the northern section of this relational area. Two devices are be installed: one in the area designated for large dogs and another in the area for small dogs.

IMAGE 8. AREA RELAZIONALE CAMPO DI MARTE BY AIR

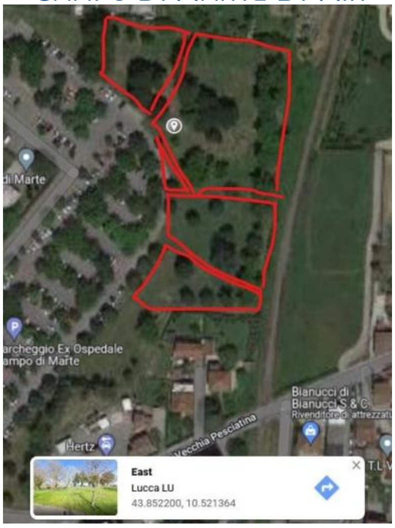


PHOTO 15. STREET VIEW AREA RELAZIONALE CAMPO DI MARTE

- **Parco Fluviale** (GPS Location: 43.855421144844065, 10.507080321802631).

  This area features two main entrances, ideal for installing people-counting devices. They are separated by 1.2 km in a straight line from the first relational area, ensuring comprehensive coverage and accurate monitoring of visitor flow.

IMAGE 9. AREA RELAZIONALE CAMPO DI MARTE BY AIR

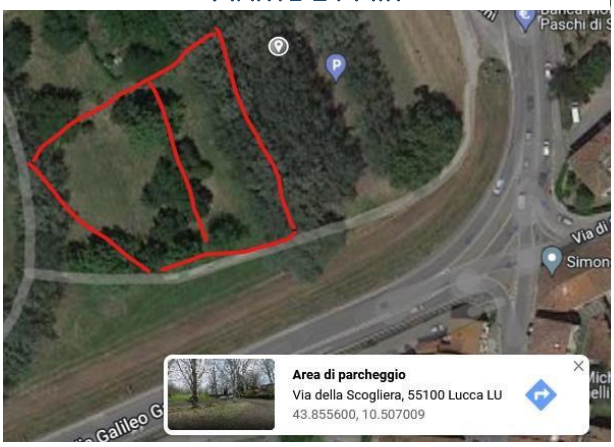


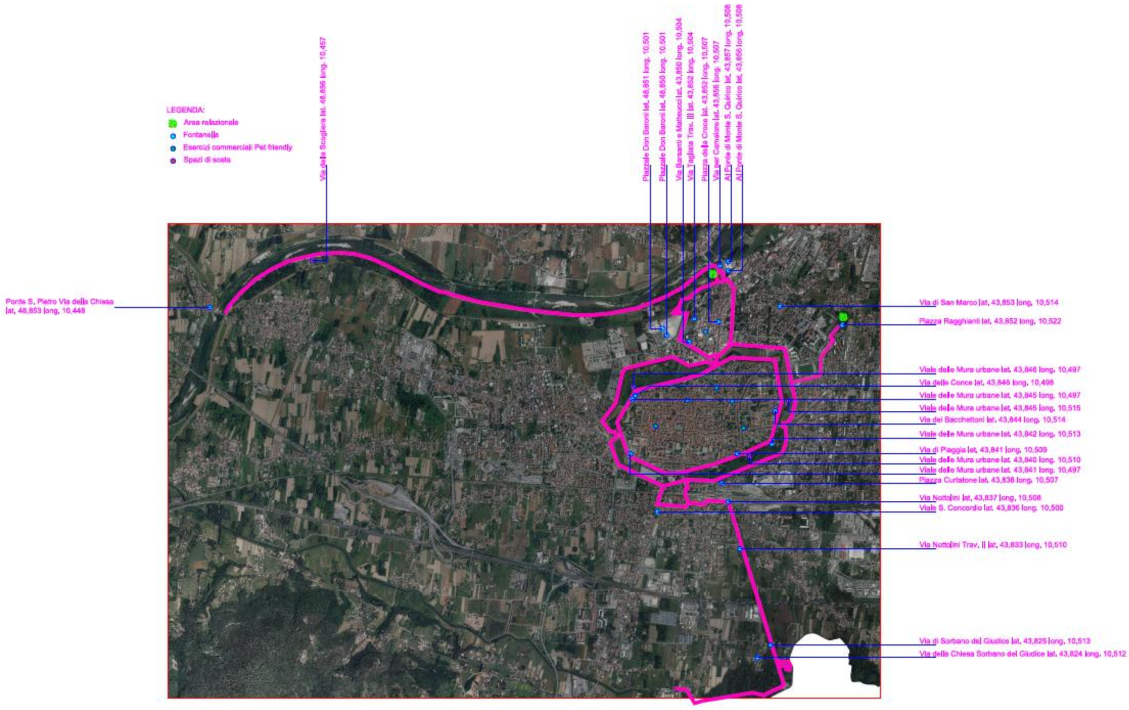
PHOTO 16. STREET VIEW PARCO FLUVIALE

The Installation

Lucca presented some challenges during installation, such as tree and leaf coverage over the solar panels, which made it difficult for the batteries to charge. To address this, the local and installation teams decided to install a box in the tree canopy. Theft was also a potential risk. Taking this into consideration, the sensors were installed on streetlight poles near access points to various pet areas.

The image shows the locations of the sensors across the relational areas and city lanes.

IMAGE 10. LOCATION OF THE RELATIONAL AREAS AND ANIMAL LANES, LUCCA



3.2.4. Nitra: Health and Wellbeing around art and environment

In Nitra, the project's objective is to establish a reversible multifunctional open-source urban landscape along the 8 km cycle road and Nitra River, which **links the peripheral Dražovce neighbourhood, the Industrial Park, and cultural and community centre Hidepark with the central city**. Several new green public spaces were developed as part of the project: two picnic meadows with multifunctional elements on each side of the corridor, one of them experimental due to its location within the river floodway. Community kitchen and workshop – the DIY Café were deployed to support community events and activities connected to the redesigned and expanded community garden. To measure the impact on people's health and well-being, specific environmental parameters are measured and collected at various points within the pilot area, as well as data occupancy of identified areas and paths, including a bike line connecting them. By integrating **air quality sensors** and **people counting devices**, the project generates valuable data to inform and enhance the use and sustainability of this urban corridor.

This data-driven approach allows Nitra to design a flexible, user-centred urban space that responds to community needs and environmental conditions. By incorporating interactive and multifunctional features, the project fosters inclusivity, promotes physical activity, and creates a lively corridor linking a peripheral neighbourhood to the city. The integration of environmental **monitoring for adaptive urban design** through a series of devices ensures the project's sustainability and long-term impact by:

- **Measuring environmental parameters** such as temperature, humidity, and CO2, the project can adapt landscaping and design elements to optimise comfort and usability throughout the year. Contrasting data with other local sources, such as weather stations from different parts of the city, can provide valuable insights into how alternative urban green spaces delivered by the project affect environmental conditions.
- **People counting for community insights** to understand usage patterns to identify peak times, popular paths, and underutilised spaces. Insights into these patterns guide the placement and design of movable multifunctional elements, ensuring they are positioned where they will have the most significant impact.
- **Evaluating social impact** by providing data on the frequency and duration of use in specific areas to help assess the success of social, cultural, and educational activities along the route. Tracking visitor numbers to public green spaces enables the evaluation of the effectiveness of NBS deployed there in fostering social interaction and enhancing community well-being. This data can uncover patterns, such as a rise in visits following specific interventions, offering tangible proof of their impact.
- **Monitoring bicycle and pedestrian traffic** to promote active mobility by highlighting areas where infrastructure improvements are needed and to elicit how people use these areas.

The Devices

- **EM500-CO2 Air Quality Sensors.**

This sensor is a robust and efficient device designed to monitor CO2 concentrations and environmental conditions. Its key features include:

- **CO2 monitoring:** Provides accurate real-time measurements of carbon dioxide levels, essential for assessing air quality.
- **Additional environmental parameters:** Measures temperature, humidity, and atmospheric pressure, offering a comprehensive view of ambient conditions.
- **Wireless connectivity:** Operates via LoRaWAN, enabling long-range data transmission with low power consumption, making it ideal for applications in smart city projects, green spaces, and environmental research

This sensor is particularly suitable for air quality monitoring in public spaces, urban environments, but also indoor areas. Its ability to measure CO2 levels and other environmental parameters helps assess air quality's impact on health and comfort. The LoRaWAN connectivity ensures reliable data transmission to the **IN-HABIT Data Platform**.

- **People Counting Camera.**

The Hikvision IDS-2CD7587G0-XZHS-Y used in Nitra is a high-performance network camera from the DeepinView series, designed for advanced analytics. Key features include:

- **High resolution:** Provides detailed imaging with excellent clarity, supporting versatile monitoring applications even outdoors.
- **Adjustable lens:** A 2.8-12mm zoom lens allows flexible field-of-view adjustments for tailored installations.
- **Privacy features:** Processes data without storing identifiable images or video, ensuring compliance with privacy regulations.

PHOTO 17. PEOPLE COUNTING CAMERA

This camera is suitable for anonymous people counting due to its AI-driven analytics, which can detect and count individuals without capturing or storing personally identifiable information. The anonymized data ensures compliance with GDPR and other privacy standards while delivering reliable metrics for monitoring foot traffic and occupancy. This makes it particularly suitable for applications like public space management and urban planning.

- **People Counting System (See 3.2.1.3).**

PAX Counter Devices are used in the Nitra pilot in open public spaces to ensure privacy and to obtain data on time spent in the area. These devices count Bluetooth or Wi-Fi enabled devices, while respecting anonymity by address hashing. The information obtained is the number of devices in the area within the last measurement period and the time spent by devices leaving the area. We are assuming that the number of devices is a rough measure that can be correlated with the number of people present in the area.

The Location

Nitra pilot area is very diverse, encompassing **residential, industrial, recreational and cultural spaces** and the newly built **cycling corridor and the river** that connects them; it offers a multitude of challenges as well as opportunities to deliver innovative solutions to boost the health and well-being of local communities. The network of sensors was designed to be installed **in 3 locations** where the most significant **IN-HABIT** solutions were deployed: the picnic meadows on the opposite sides of the corridor and in the outdoor cultural and community centre Hidepark.

Image 11. A. Nitra Pilot Area. B. Picnic Meadow In River Floodway. C. Hidepark (Community Garden, Community Kitchen And Workshop). D. Picnic Meadow Dražovce

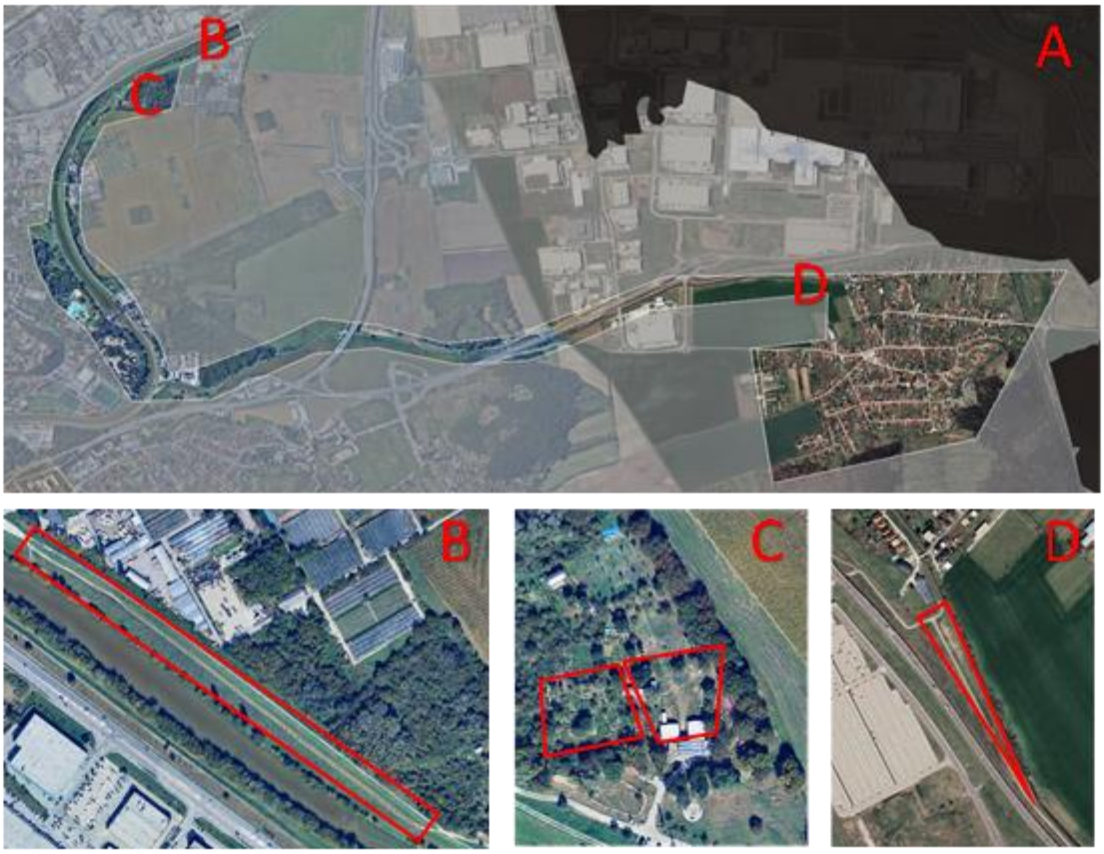


Photo 18. Location C2 – Community Garden In Hidepark (Coordinates: 48.3153885,18.0669354)

Photo 19. Location D – Picnic Meadow Dražovce (Coordinates: 48.3460270,18.0560612)

The Installation

In Nitra, the local and installation team faced several challenges while setting up the devices:

- **Open areas with multiple entry points**: In locations B and D, the openness of the spaces made it difficult to control access. To address this, the team used two alternative people-counting methods.
- **Lack of an electrical network**: The absence of a power supply at the installation points required alternative solutions.
- **Remote locations and security concerns**: The remoteness of the areas necessitated mounting devices at significant heights to prevent theft or vandalism.
- **Permission issues**: Securing the necessary permissions to install poles for mounting cameras proved challenging.

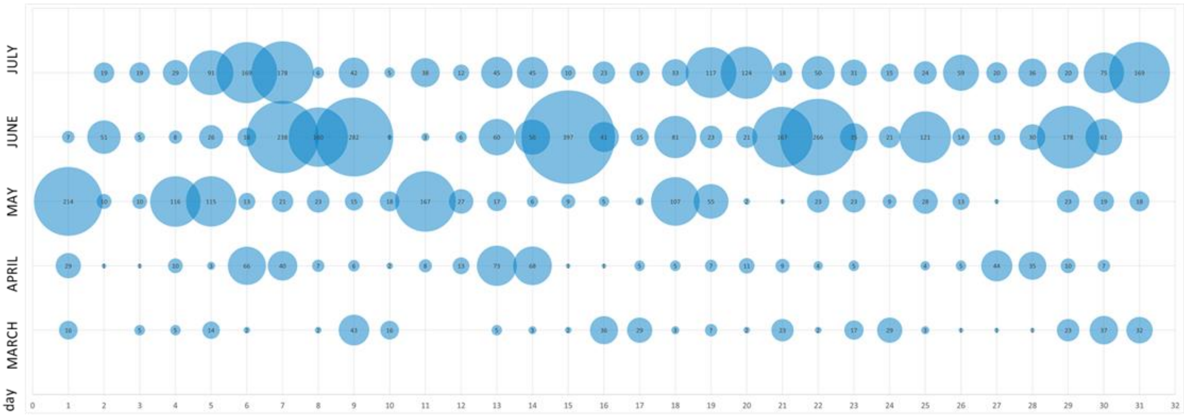
The network of sensors in Nitra is comprised of the following:

- **Air Quality Sensors** are intended for installation in the community garden.
- The **People Counting Camera** was mounted at location C (Hidepark) in the entryway into the section of the space where most activities are organised. Before the availability of the **IN-HABIT** Data Platform, the camera was connected to the local Wi-Fi network, and the data were downloaded from the camera directly (PHOTO 23 shows the data analysis example).
- **6 modified PAX Counter Devices** are to be installed at the entry and exit points of the two picnic meadows. Already existing structures (light poles, old phone-line poles etc.) are used for mounding the sensors where possible, to minimize the delays caused by permit issues (Photo 20).

PHOTO 20. STRUCTURES USED TO MOUND SENSORS IN OPEN PUBLIC SPACES

PHOTO 21. PEOPLE COUNTING CAMERA INSTALLED AT HIDEPARK

IMAGE 12. ILLUSTRATION OF DATA ANALYSIS FROM PEOPLE COUNTING CAMERA AT HIDEPARK BEFORE THE AVAILABILITY OF IN-HABIT DATA



3.2.2. Interconnection layer

The IN-HABIT Data Platform consists of two key components: a **LoRaWAN** server interconnection service from The Things Network (TTN) and the **FIWARE** Orion Context Broker. Together, these components enable seamless data collection, processing, and management for IoT-based environmental monitoring.

The Things Network (TTN) is a global, open-source initiative designed to simplify the deployment and management of LoRaWAN (Low Power Wide Area Network) infrastructure for IoT devices. TTN provides low-cost, long-range, and energy-efficient connectivity and operates on a community-based model that encourages shared infrastructure. Individuals and organizations contribute to the global network by adding their gateways, creating a collaborative ecosystem. TTN offers tools for provisioning, monitoring, and routing IoT device data, making it an ideal solution for **the IN-HABIT Data Platform**. This open LoRaWAN coverage model allows to leverage both its own gateways and those of the community.

The FIWARE Orion Context Broker, a core component of the FIWARE platform, manages real-time context information, enabling smart applications to efficiently access and use data via its NGSI-v2 API. TTN forwards IoT device data to the FIWARE Context Broker using the NGSI-LD API, where the data is processed and stored as entities. The Context Broker continuously updates these entities' states in real time, ensuring accurate and up-to-date information for analysis and decision-making.

3.2.3. Knowledge layer

The function of this layer is to process and analyse the collected data to generate actionable insights.

The IN-HABIT Data Platform use the **Quantum Leap FIWARE** Generic Enabler for trend analysis and temporal Big Data queries to manage time-series data generated by the IoT devices subscribed to our FIWARE Context Broker and persist context updates as time-series data into a CrateDB database.

CrateDB is a distributed SQL database optimized for managing large volumes of time-series and machine data. It combines the familiarity of SQL with the scalability and flexibility of NoSQL, making it ideal for IoT, industrial applications, and real-time analytics. It acts as a central repository for contextual data, providing a standard interface for accessing and managing this data.

Contextual data refers to any information that can describe the current state of the environment, such as the location of a device, the status of a sensor, or any other data that can be used to understand the current state of a system. The Orion Context Broker stores this information in a structured format called a "context data model".

The Orion Context Broker provides a RESTful API that allows applications and other components of the system to access and manipulate context information. The API allows for querying and filtering of context information, as well as updating and deleting context information. The API is designed to be lightweight and efficient, allowing for fast access to context data.

3.2.4. Interoperability layer

The interoperability layer in the IN-HABIT Data Platform is critical as it enables seamless integration, communication, and collaboration between diverse systems, applications, and stakeholders.

The Platform relies on an array of heterogeneous data sources and technologies—such as different IoT devices, Open Data APIs, or citizen data collected by the IH-HABIT App, each of which may use different protocols, data formats, and standards. The interoperability layer ensures that data from these disparate systems can be integrated into a unified platform, allowing them to exchange information regardless of its form factor.

3.2.4.1. Technological Interoperability

Technological interoperability, and the cornerstone of FIWARE technology framework is based on standards and open source and free documentation. FIWARE is supported by a large community that has developed various enablers and connectors, making it possible for the **IN-HABIT Data Platform** to interface with any entity or organisation.

Using docker containers technological interoperability allows the Platform to define portable systems easily movable among physical servers, cloud servers or even personal computers avoiding any type of vendor lock-in.

3.2.4.2. Data Interoperability

Data interoperability refers to the ability of different systems, applications and organisations to exchange, interpret and use data effectively, regardless of their origins or formats.

The **IN-HABIT Data Platform** has two sides where interoperability is essential. The first is on **the data collection side** (input interoperability), as data comes from different types of devices, from different manufacturers, different units of measurement, as well as different formats and encodings.

The second is on the **data consumption side** (output interoperability). Once collected and processed the data, it must be delivered in a form in which it is easily consumable. The data formats must be standardised, the query APIs must also be known and well documented, and the semantics of the information provided must be defined and contextualised to make it easy for both humans and machines to make use of the data.

3.2.5. Presentation layer

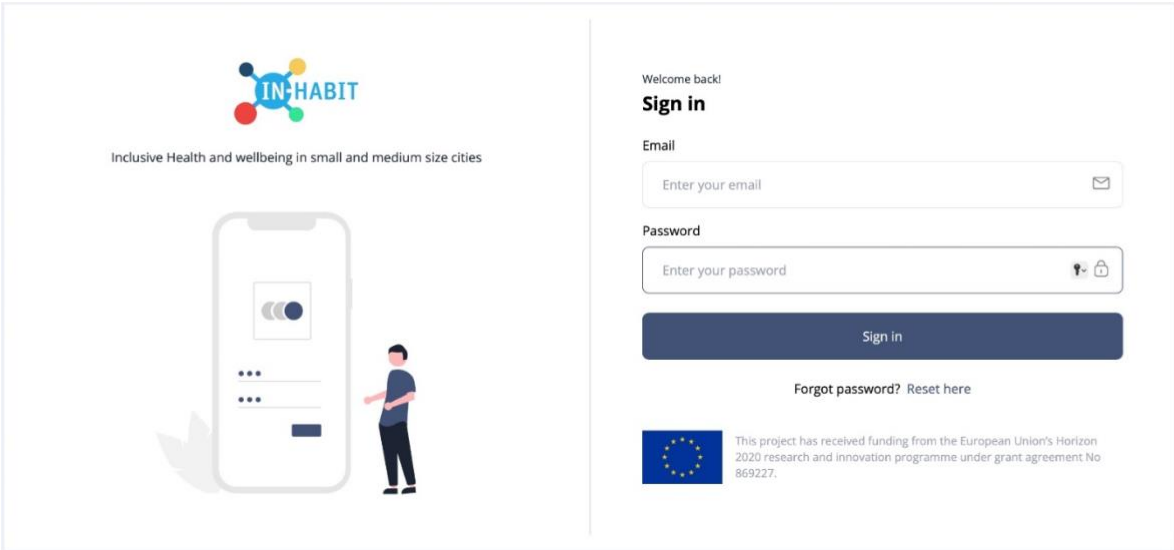
The presentation layer of the **IN-HABIT Data Platform** is responsible for the user interface and the visualization of data and information collected by the platform. It provides a user-friendly port for the citizens, policymakers and other stakeholders.

This layer includes various components such as dashboards, maps, charts, and other visualizations that enable users to easily understand the data and make informed decisions. It also provides real-time alerts and notifications to keep users informed of anyevents or anomalies in the city's operations.

Overall, the presentation layer plays a crucial role in making the data collected for this project accessible, understandable, and actionable for all stakeholders, including citizens, businesses, and city officials.

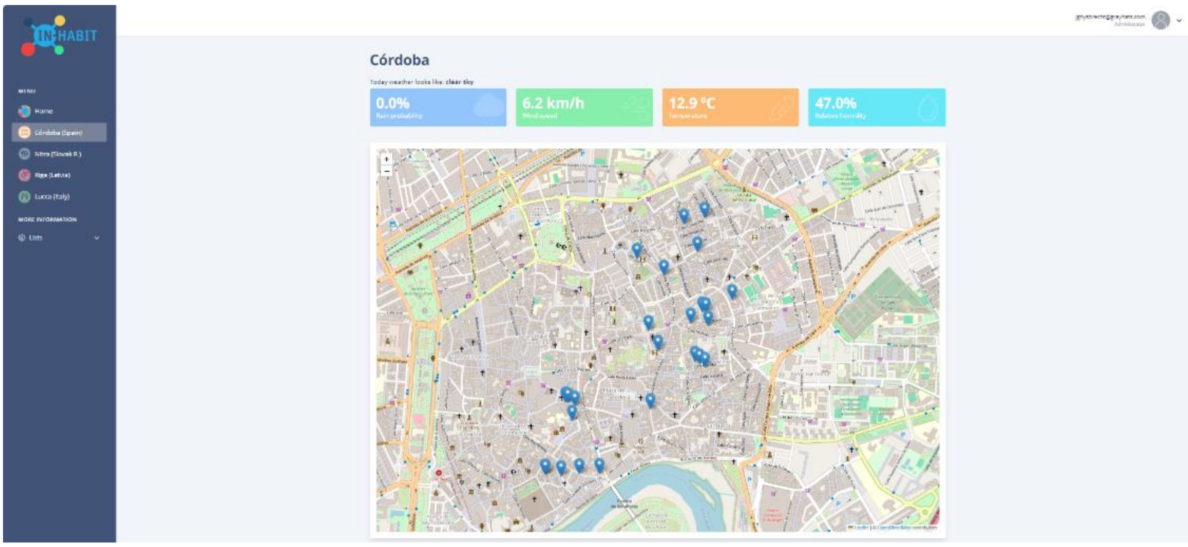
The main **dashboard** shows the four different cities involved in the **IN-HABIT** Project. The user may then select the desired city to access the relevant data for each one. The API is available to use by **IN-HABIT** Partners, Metric Participants (such as Patio owners) and any policy maker in: https://in-habit.grayhats.com/login

IMAGE 13. PLATFORM ACCESS



View of the **IN-HABIT Data Platform**'s login screen, featuring a simplified interface for secure and easy access to sensor data and analysis.

IMAGE 14. SENSOR SYSTEM BY CITY. CORDOBA

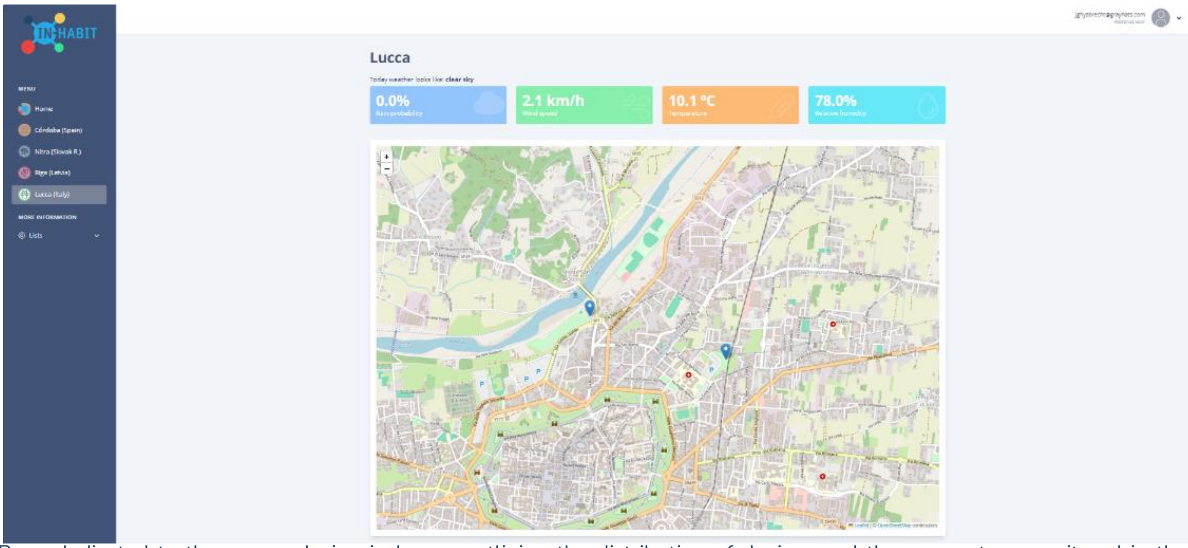


Page dedicated to the sensor design in Cordoba, outlining the distribution of devices and the parameters monitored in the patios selected for the **IN-HABIT** project.

Image 15. Sensor System By City. Riga

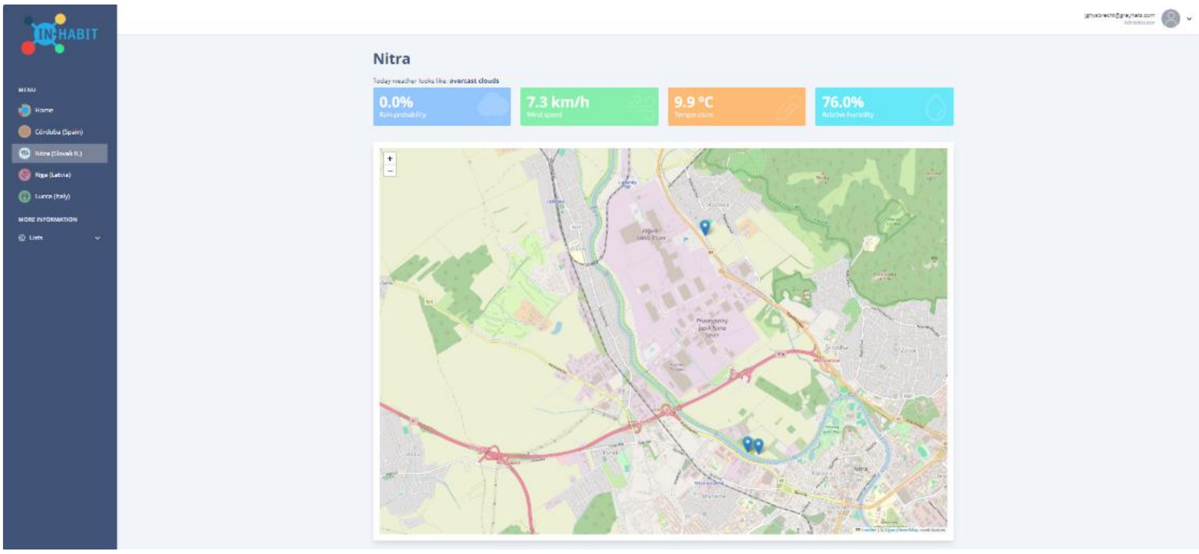
Page dedicated to the sensor design in Riga, outlining the distribution of devices and the parameters monitored in the market location selected for the IN-HABIT project.

Image 16. Sensor System By City. Lucca



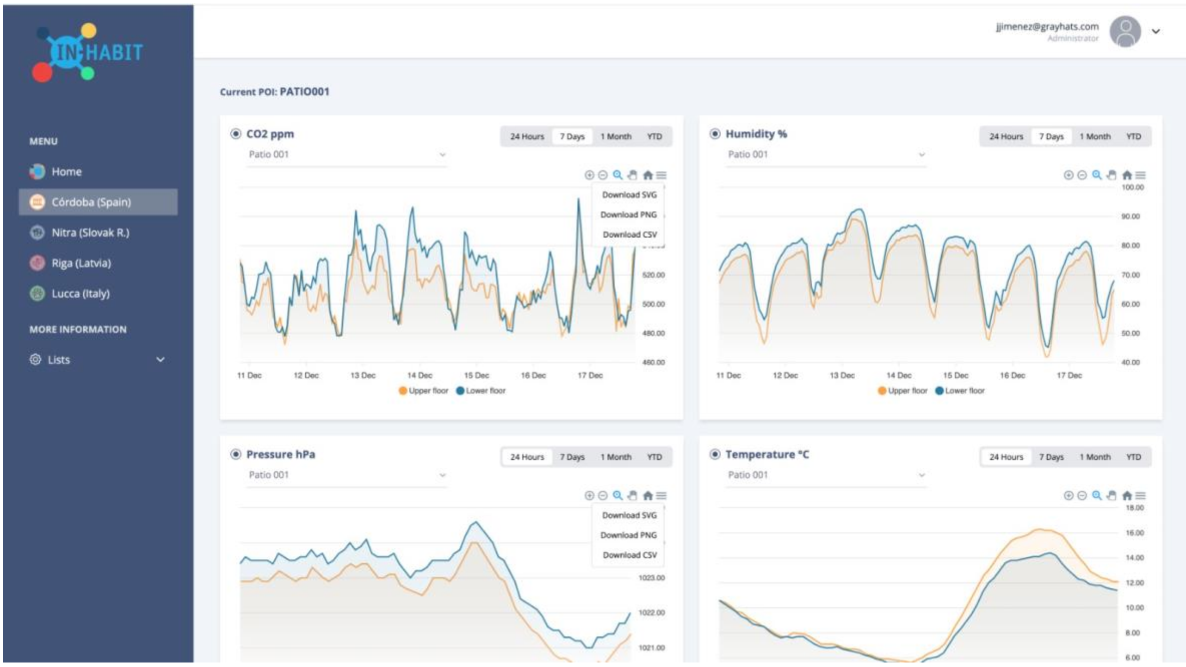
Page dedicated to the sensor design in Lucca, outlining the distribution of devices and the parameters monitored in the relational areas created for the **IN-HABIT** project.

Image 17. Sensor System By City. Nitra



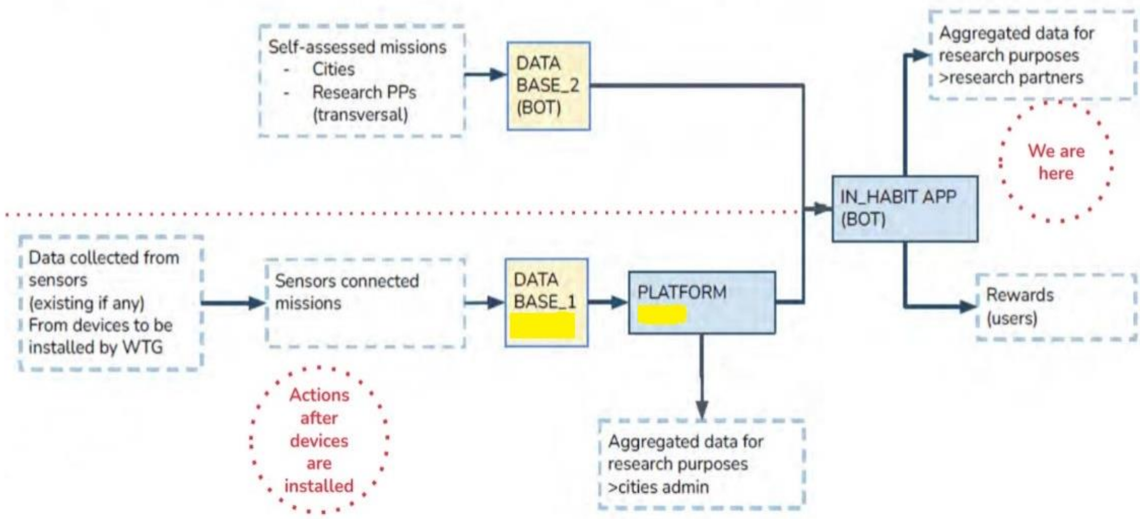
Page dedicated to the sensor design in Nitra, outlining the distribution of devices and the parameters monitored in the cycle lanes created for the IN-HABIT project.

Image 18. Type Of Use: Sensor Graphs And Downloads



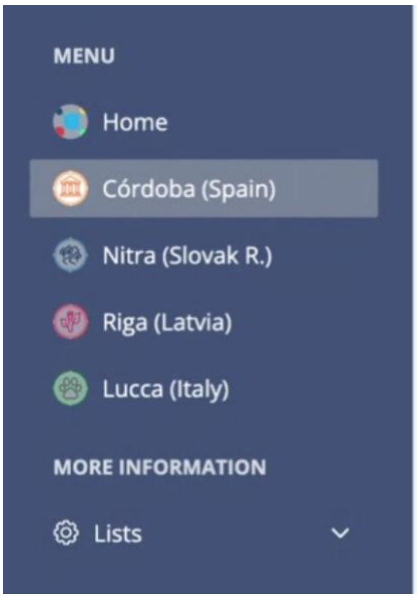
Page dedicated to the design of sensors in Cordoba, detailing the distribution of devices and the parameters monitored in the relational areas developed for the **IN-HABIT** project.

Image 19. Integration With Other Apps And APIs



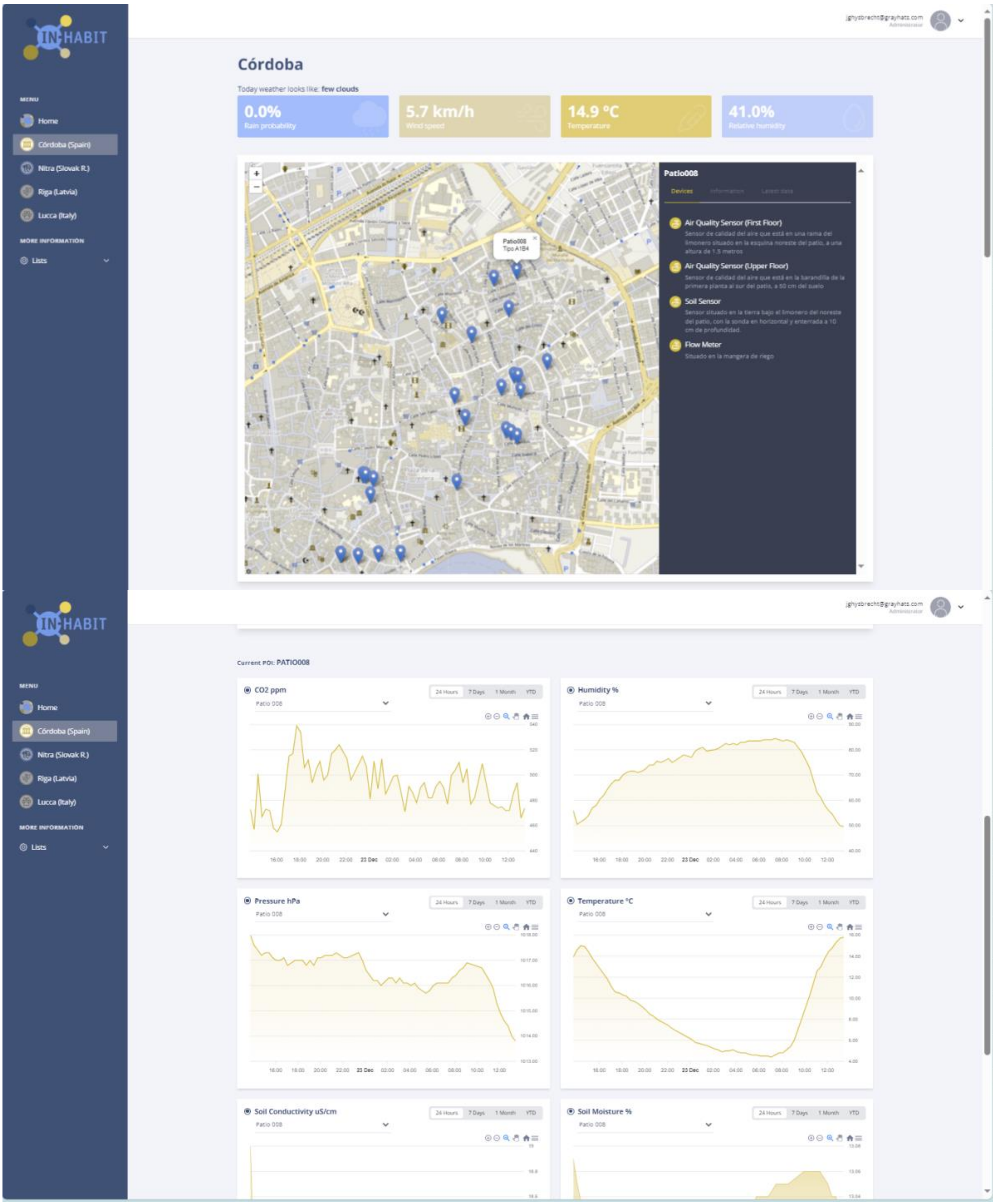
Model of the integration of the **IN-HABIT Data Platform** in terms of its integration with other products such as the app designed by the BOT Partner.

Image 20. Geo Loc



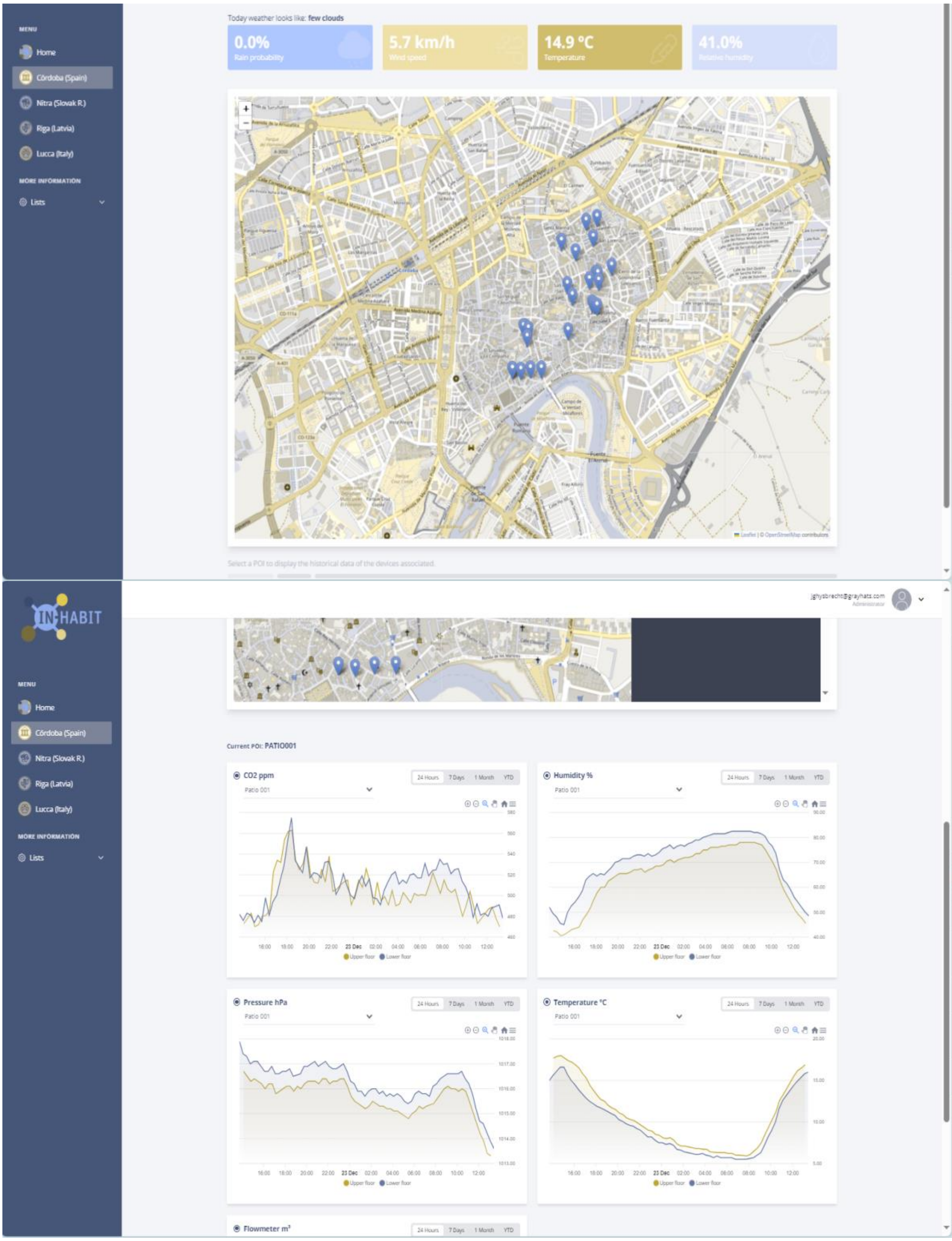
Page dedicated to the geographical location filer of the IN-HABIT Data Platform.

IMAGE 21. INCLUSIVITY. DEUTERANOPIA COLOUR BLINDNESS MODE



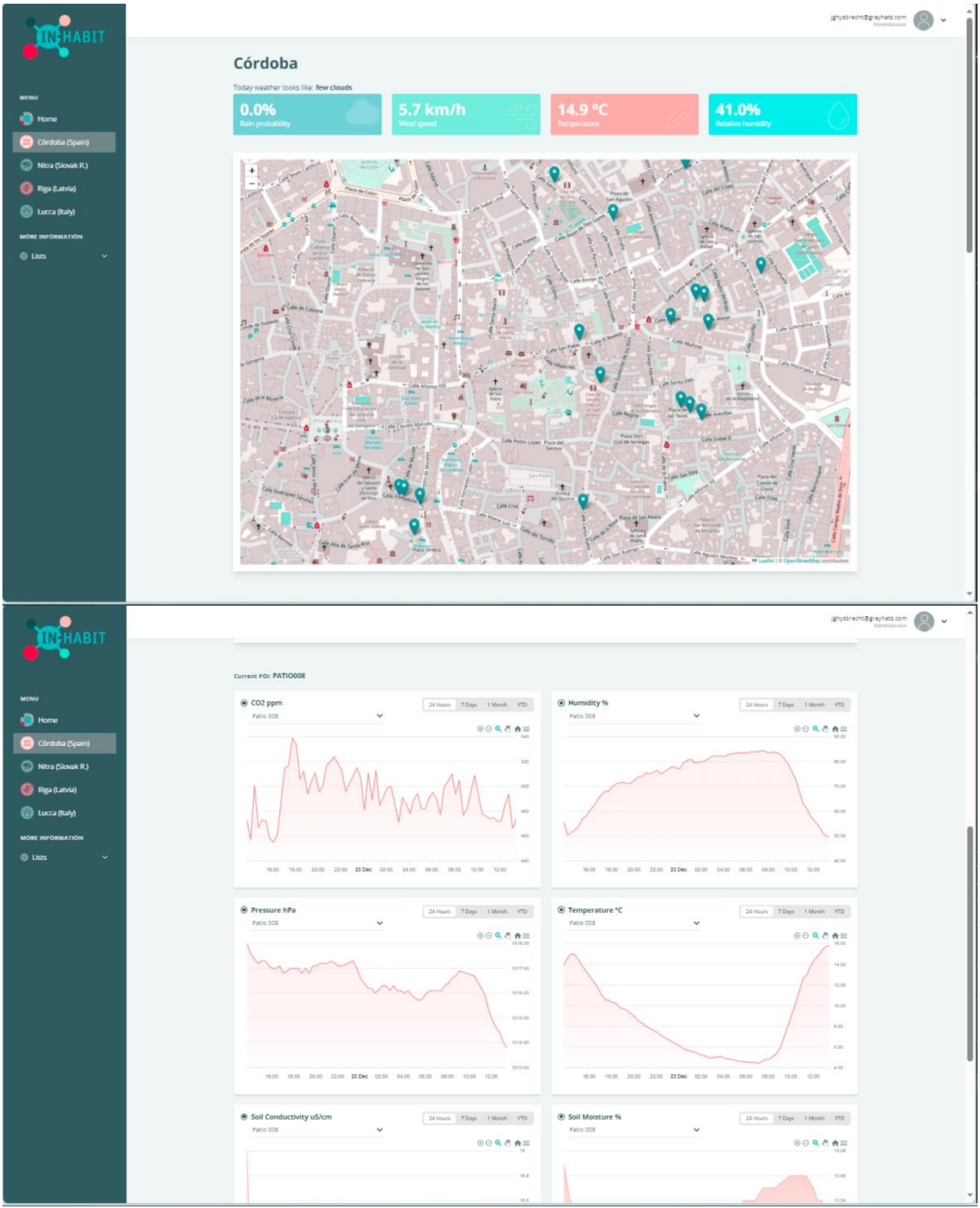
These series of images demonstrate how the platform is user-friendly for individuals with visual impairments, specifically those related to colour perception, such as colour blindness.

IMAGE 22. INCLUSIVITY. PROTANOPIA COLOUR BLINDNESS MODE



These series of images demonstrate how the platform is user-friendly for individuals with visual impairments, specifically those related to colour perception, such as colour blindness.

IMAGE 23. INCLUSIVITY. TRITANOPIA COLOUR BLINDNESS MODE



These series of images demonstrate how the platform is user-friendly for individuals with visual impairments, specifically those related to colour perception, such as colour blindness.

ANNEX: IN-HABIT Data Platform User's Guide

Welcome to the IN-HABIT Platform. This guide is designed to help researchers involved in the IN-HABIT project and their collaborators navigate and efficiently use the platform. Below, you will find detailed instructions on how to access the platform, manage your credentials, understand access levels, troubleshoot common issues, and utilise the platform's advanced features.

1. Introduction

The **IN-HABIT Data Platform** is a comprehensive tool aimed at facilitating research and collaboration among members of the **IN-HABIT** project and its collaborating groups. The platform is organised into four main sections, each corresponding to a participating city: Córdoba, Riga, Nitra, and Lucca.

Accessing the Platform

Access URL

To access the platform, open your web browser and navigate to:

https://in-habit.grayhats.com/login

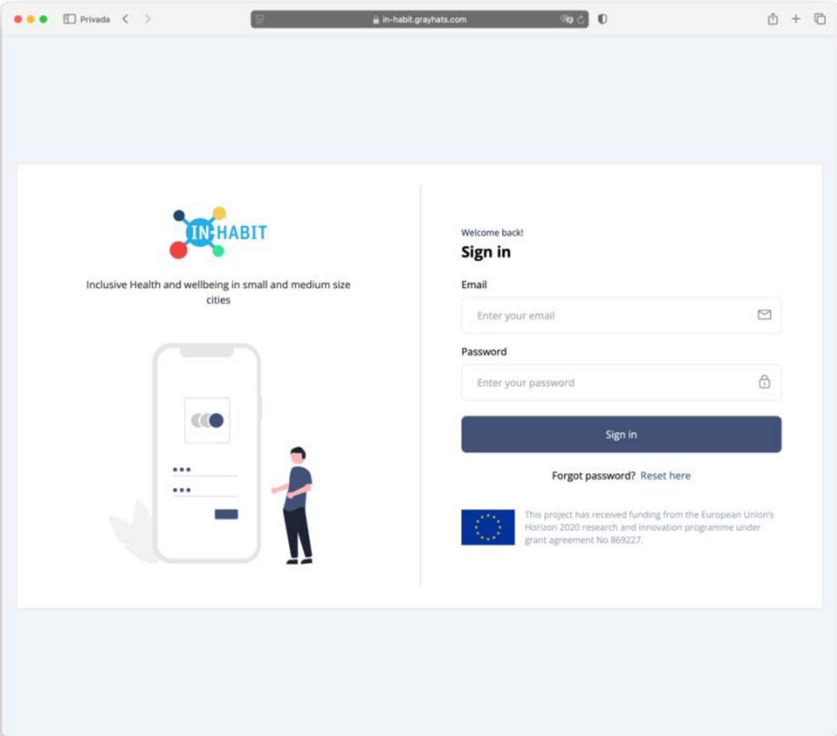
Login Process

Enter Credentials:

Username: Enter your username.

Password: Enter your corresponding password.

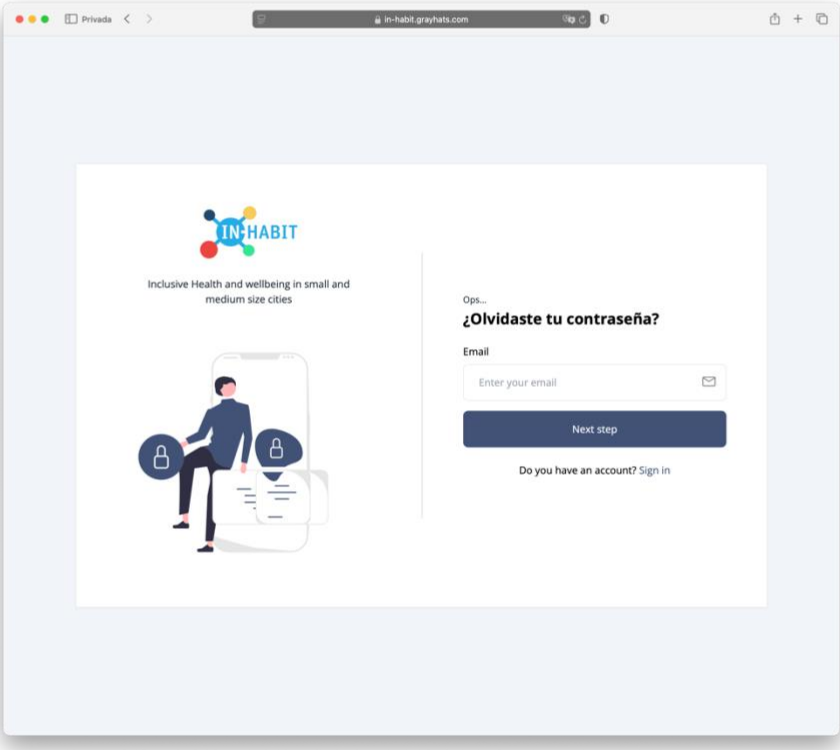
Log In:
Click the **"log in"** button.



If you encounter difficulties accessing the platform, follow these steps:

Verify Your Credentials:

1. Ensure that your username and password are correct.
2. **Use an Incognito Window**: Open a new incognito tab in your browser. Attempt to access the platform again using the login process.
3. **Reset your password.**
4. **Seek Assistance:** If the issue persists, contact your organisation's administrator for additional support.



Requesting Credentials

If you are part of the **IN-HABIT** project or one of the collaborating groups but do not yet have access credentials, follow these steps to request them:

1. **Contact the Administrator:** Reach out to your organisation's administrator within the IN-HABIT project.
2. **Provide Necessary Information:** Supply your full name, email address, and the organisation you belong to (Córdoba, Riga, Nitra, or Lucca).
3. **Await Confirmation:** The administrator will process your request and provide you with your access credentials.

2. Access Levels

The **IN-HABIT Data Platform** features three access levels that determine which content and functionalities are available to each user:

City User (User)

- **Access**:
    - Customised Dashboard: Exclusive access to the dashboard of the organisation you belong to.
- **Permissions:**

- View and analyse data specific to your dashboard.
- Access Assigned POIs: You can only access Points of Interest (POIs) that have been assigned to you. Within these POIs, you will have full functionality.

City Manager (Admin)

- **Access:**
  - City Content: Full access to all content and functionalities of the city you manage.
- **Permissions:**
  - Manage users within your city.
  - Access and modify data relevant to your city.
  - Manage the creation of users specific to your city.
  - Access to All POIs in Your City: You can access the dashboards of all POIs within your city.

Admin (Superadmin)

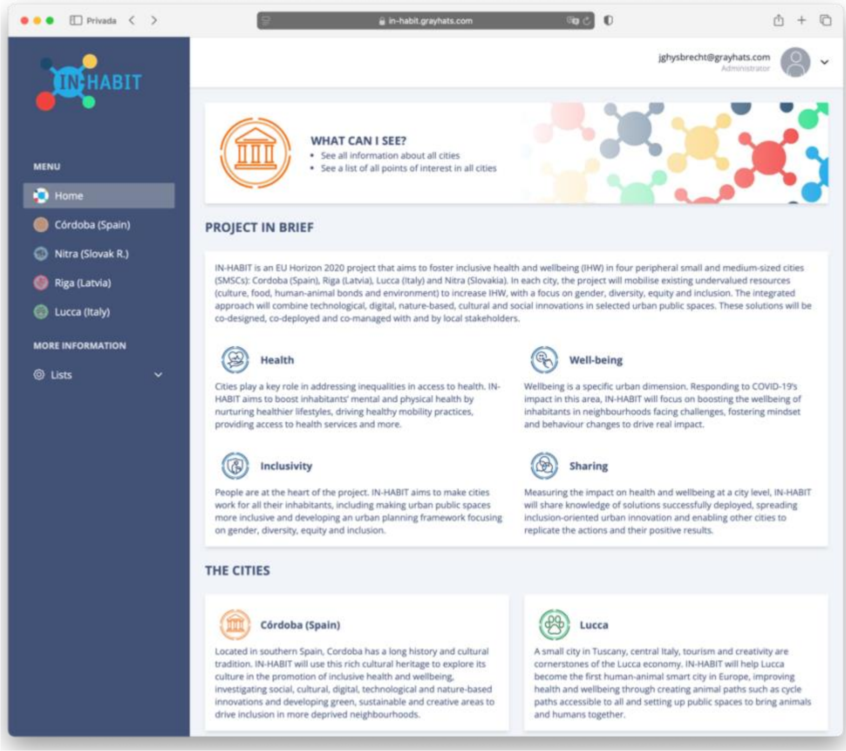
- **Access:**
  - Entire Platform: Full access to all functionalities and content across the four cities (Córdoba, Riga, Nitra, and Lucca).
- **Permissions:**
  - Manage all users and administrators across all cities.
  - Access to All POIs: You can access the dashboards of all POIs in all cities.
  - Access and modify data from any city.
  - Configure and maintain the platform.

3. Navigating the Platform

The platform is divided into four main sections, each corresponding to a participating city:

1. **Cordoba:** Access Córdoba-specific data and tools.
2. **Riga:** Access Riga-specific data and tools.
3. **Nitra:** Access Nitra-specific data and tools.
4. **Lucca:** Access Lucca-specific data and tools.

Below are the primary navigation and usage functionalities of the platform.

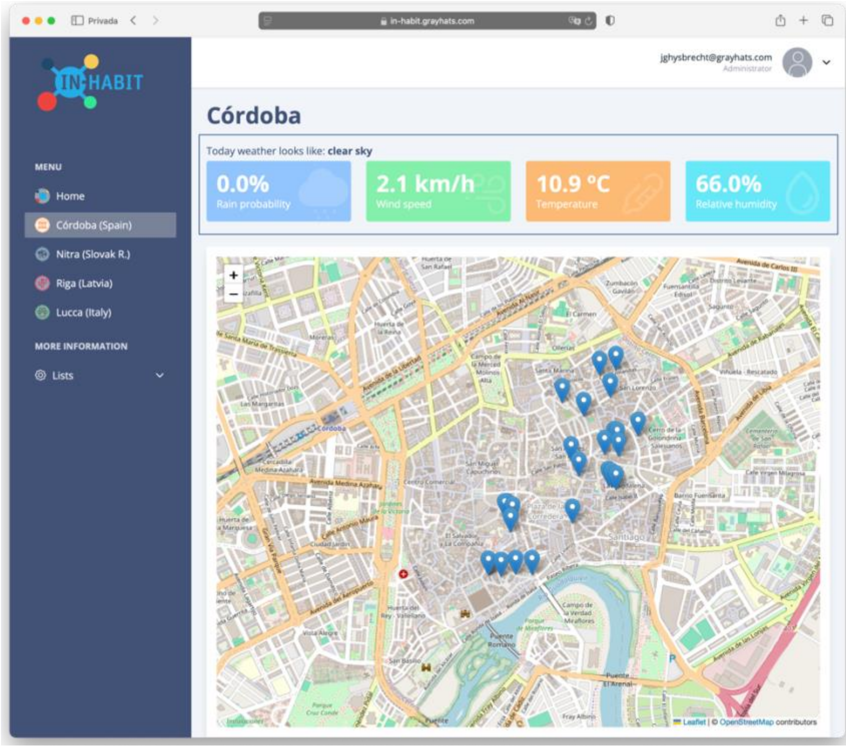


Access to Sections

From the Main Dashboard: Select the corresponding city from the side navigation menu. If your privileges are set to Admin or User, this step will not be necessary as you will be automatically redirected to the page for which you have access rights.

User Interface: Each section provides interactive charts, reports, and analytical tools tailored to the needs of the selected city. Additionally, each page includes a real-time weather information panel, an interactive map, and dynamic charts for enhanced data exploration and analysis.

More information, Points of Interest (POIs): In the platform navigation, a Lists/Point of interest view is displayed. This view is only accessible to admins and shows a list of all POIs.



Map Navigation

Responsive Map and POIs

- Interactive Map:
  - The map is fully responsive, meaning it adapts to different screen sizes and devices.
  - You can zoom in and zoom out using the zoom controls or by scrolling with your mouse wheel.
- POI Markers:
  - Each POI is represented by a marker on the map.
  - Clicking on a marker will display the corresponding POI's dashboard in a side pane.
- Access based on User Level
  - User (User): can only Access the POIs assigned to them.
  - Administrator (Admin): tienet acceso a todos los POI de la ciudad que administra.
- Superadministrator (Superadmin): Has access to all POIs across all cities (Córdoba, Riga, Nitra, and Lucca).

Side Panel Navigation

Upon selecting a POI on the map, a side panel will open displaying detailed information about the selected POI. This panel is divided into three tabs:

- **Devices:**
  - Sensor Overview: Displays the sensors installed at the POI.
  - Sensor Description: Includes a description of the exact location of each sensor within the POI.
- **Information:**
  - POI Characteristics: Presents a table detailing the POI's characteristics, such as its name, location, type of point of interest, and other relevant data.
- **Latest Data:**
  - Real-Time Data: Shows the latest data generated by each of the devices installed at the POI.
  - Automatic Updates: Data is updated automatically to reflect the most recent information from each sensor.

Changing POIs: To select a new POI, simply click on another marker on the map. The side panel will automatically update to display information relevant to the newly selected POI.

Navegating the Charts

The platform offers interactive graphs that allow data to be analysed visually and dynamically. Each graph has a series of control buttons that facilitate interaction and customisation of the visualisation:

- Temporal Filters:
  - 24 Hours: Displays data from the last day.
  - 7 Days: Displays data from the last week
  - 1 Month: Displays data from the last month.
  - YTD (Year To Date): Displays data from the current year.

  Use: Selects the desired time period to adjust the display of the data on the graph.
- Zoom Controls:
  - Plus (+): Zooms in to view more specific details.
  - Minus (-): Zooms out for a wider view of the data.

- Navigation Tools:
  - Magnifying glass: Allows you to select a specific set of data within the chart.
  - Hand: Allows you to scroll laterally through the data.
  - Mouse Selection: You can select time periods by dragging the cursor over the graph.
- Reset Display:
  - Home Icon: Resets the graph display to its default state.

Downloading Content

Each chart in the platform has a download button represented by three horizontal lines. Clicking this button will display a menu with the following options:

- Download SVG:
  Description: Download an image of the graphic in SVG format with a transparent background.
  Use: Ideal for inclusion in documents or presentations where a transparent background is required.
- Download JPG:
  Description: Download an image of the graphic in JPG format with a white background.
  Usage: Useful for static images or reports that require a solid background.
- Download CSV:
  Description: Downloads a delimited text file (CSV) with the data shown in the chart.
  Considerations:
  - Current Data: if you have a week's worth of data selected, this will be the data that will appear in the file after downloading.
  - All Data: To download all available data, make sure that the graph shows all the values before downloading.
- View Values: You can view the value of a particular point on the graph by hovering your cursor over it. This will allow you to get precise details of the data represented.

Filter by POI

On each graph, there is a drop-down to select the POI of interest. Once a POI is selected, all the graphs will be updated to show the data corresponding to that POI.

Single Display: Currently, it is not possible to display graphs belonging to different POIs on the same dashboard. Each complete dashboard will be linked to only one POI at a time.

4. Troubleshooting Common Problems

I Cannot Log into My Account

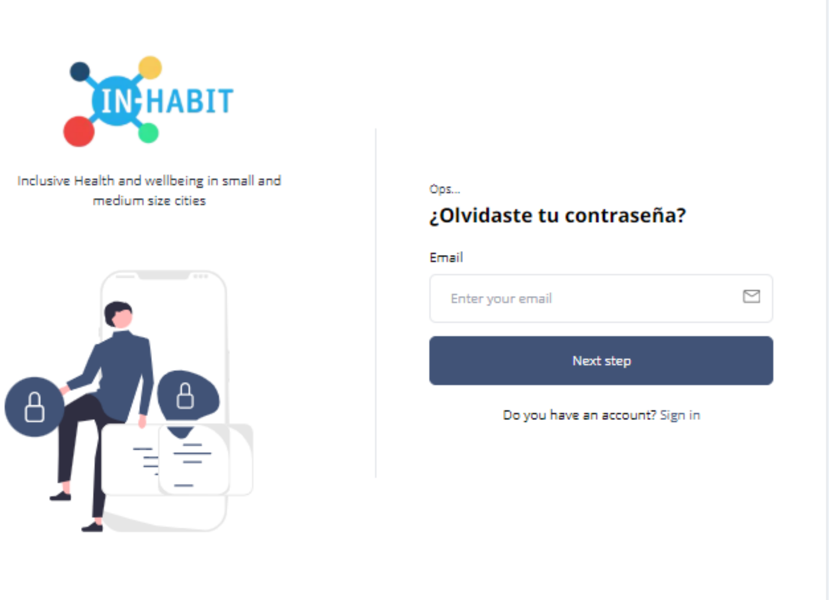
Step 1: Verify that you are using the correct username and password.

Step 2: Try logging in from an incognito window in your browser.

Step 3: If the problem persists, contact your organisation's administrator to reset your credentials.

I Forgot my Password

The platform has an automatic password recovery option. You will need to click on 'Forgot password? Reset here' and enter the email address associated with your account to request a password reset.



I Don't Have Access to the City I Need

Make sure your account has the appropriate access level (City User, City Manager or Admin) and is assigned to the correct city. Contact your organisation's administrator to verify or update your permissions.

Technical Problems or Platform Errors

- **Restart your Browser:** Close and re-open your browser.
- **Refresh the Page:** Press F5 or the refresh button on your browser.
- **Use Another Browser:** Try accessing the site from a different browser.
- **Contact Technical Support:** If the problem persists, contact the **IN-HABIT Data Platform** technical support team.

5. Contact and Support

For any queries, further assistance or to report technical problems, please contact your organisation's administrator or the **IN-HABIT Data Platform** support team via:

- **Email: inhabit.support@grayhats.com**
- **Phone: +34 957858977**

6. Additional Tips

Keep your Credentials Secure: Do not share your username and password with other users.

Update your Information: If you change roles or cities within the project, inform the administrator to update your permissions.

Explore Functionalities: Familiarise yourself with the different tools and reports available on your dashboard to get the most out of the platform.

Use the Navigation Tools: Take advantage of the map navigation and charting features to better understand and analyse your data.

Download and Analyse Data: Use the download options to export data and graphs for reporting and analysis outside of the platform.