PROJECT TEMPLATE

Development of a MeteoBus Network in a Metropolitan Area to Support Climate Change Adaptation

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Objective: to leverage the existing public transport network as a mobile sensing infrastructure, integrating it with fixed sensing systems to create a unified urban microclimate observation network combining high temporal continuity with high spatial resolution in support of climate change adaptation strategies

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1. Background and objectives

Within a metropolitan Smart City system, the **MeteoTracker MeteoBus platform** provides an opportunity to implement an **advanced urban microclimate monitoring system** designed to support climate change adaptation policies, urban planning and the assessment of Urban Heat Island mitigation measures.

The proposal envisages integrating the MeteoTracker platform with the metropolitan area's Smart City infrastructure by transforming part of the urban and metropolitan public transport fleet into a distributed network of mobile weather stations.

The proposed paradigm is “vehicle as a sensor”: during normal service, public transport vehicles automatically acquire georeferenced meteorological and environmental data, producing continuous, high-resolution mapping of the urban microclimate.

The objective is to complement the existing fixed-sensor network with a mobile component capable of increasing the spatial coverage of observations by orders of magnitude, creating a single information infrastructure in which fixed stations and mobile sensors perform complementary functions.

The fixed network provides high temporal continuity at a limited number of locations, while the MeteoBus network captures microclimatic variability across the entire urban fabric, down to individual street scale.

2. Development of the MeteoBus network

The mobile monitoring component will be implemented by **installing MeteoTracker Standalone devices** on public transport vehicles operating throughout the metropolitan area.

The MeteoTracker Standalone configuration is specifically designed for fleet applications and enables fully automated data collection without requiring any driver interaction.

The system includes:

- **MeteoTracker sensor for measuring meteorological parameters;**
- **onboard GNSS/4G communication and geolocation module;**
- **automatic data transmission to the MeteoTracker cloud infrastructure;**
- **measurement quality-control algorithms;**
- **remote management and supervision of the device network.**

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The MeteoBus platform can also integrate the **MT-Infrared sensor**, designed to measure **road-surface temperature** using infrared technology. Simultaneous acquisition of air temperature and pavement temperature extends the thermal characterization of the urban environment and supports analysis of road-surface behaviour under different weather and solar-radiation conditions.

Automated operation makes it possible to transform normal public transport service into a mobile **permanent environmental monitoring network**, without interfering with fleet operations.

Each measurement is associated with a geographical position, timestamp and device identifier and is transmitted to the cloud for subsequent validation, processing, historization and distribution.

3. Selection of routes to be equipped with MeteoTracker

The selection of public transport routes to be equipped with MeteoTracker devices is an important factor in maximizing the **information value** of the network.

Priority should be given to routes providing the best possible coverage of different types of urban fabric and the main microclimatic conditions found across the metropolitan area. Selection criteria may include:

- overall geographical coverage;
- coverage of the most densely built urban areas;
- neighbourhoods characterized by limited vegetation;
- parks and green infrastructure;
- peripheral residential areas;
- commercial and industrial areas;
- school and healthcare areas and locations with a high presence of vulnerable populations;
- connections between the urban centre and municipalities in the metropolitan area, including routes crossing non-urbanized areas.

The objective is therefore not simply to increase the number of kilometres monitored, but to establish **a set of microclimate observation corridors** representative of different urban characteristics.

4. Sizing of the mobile network

For each selected route, multiple vehicles can be equipped with MeteoTracker Standalone devices. The number of equipped vehicles directly determines **the spatial and temporal density** of the monitoring network: the greater the number of MeteoTracker units deployed, the higher the frequency of observations along each route and the more comprehensive the coverage throughout the day.

Increasing the number of equipped vehicles provides, simultaneously:

- higher observation frequency at individual locations;
- better representation of the daily temperature cycle;
- greater statistical robustness;
- fewer periods without observations;
- the ability to compare measurements from different vehicles;

This creates a genuine **permanent urban microclimate observation system** with spatial resolution on the order of metres.

5. Virtual Fixed Stations (VFS)

A particularly important element of the proposal is the use of the MeteoTracker platform's **Virtual Fixed Stations (VFS)**.

A VFS is a defined geographical point within the territory associated with a **capture area**, generally circular and with a configurable radius.

Whenever a MeteoTracker-equipped vehicle passes through this area, the measurements collected are **automatically associated with the VFS**.

Successive passages by different vehicles make it possible to build a **time series** for a fixed location over time, while using only sensors installed on moving vehicles.

In other words, a mobile network can generate **a virtually unlimited number of permanent observation points** without requiring the physical installation of an equivalent number of stations.

5.1 Selection of VFS locations

A network of VFS is proposed at locations with **high information value**.

Locations where fixed weather stations have already been installed as part of previous Urban Heat Island analysis projects are of particular interest.

Geographical co-location of a fixed station and a MeteoTracker VFS would enable:

- direct comparison between fixed and mobile observations;
- *cross-validation* of the data;
- assessment of the spatial representativeness of existing stations;
- analysis of microclimatic variability in surrounding areas;
- systematic study of differences between point and mobile measurements.

Additional VFS may be located at:

- squares and pedestrian areas;
- schools;
- hospitals;
- parks;
- major green infrastructure;
- waterfront areas;
- densely built neighbourhoods;
- areas subject to project interventions;
- mobility hubs;
- areas identified as climatically vulnerable.

6. Integration with the metropolitan Smart City platform

The MeteoTracker platform includes a **cloud infrastructure** dedicated to the collection, validation, georeferencing, historization and distribution of data from the mobile network.

The proposal is to retain this infrastructure as the **specialized layer for managing the MeteoBus component** and to integrate the resulting data into the metropolitan area's IoT/Smart City platform **via APIs**.

In this way, the municipal platform can simultaneously access data from fixed stations, measurements acquired by mobile MeteoTracker units and data captured by VFS.

The different sources will remain identifiable through appropriate metadata while being used within the same visualization and analysis environment.

This approach also **avoids infrastructure duplication** by using the functions already available in the MeteoTracker platform for the specific management of mobile sensing, while leaving the Smart City platform responsible for aggregating and leveraging the different territorial information sources.

7. Specialist analysis of microclimate data

The MeteoTracker platform makes available a **massive stream of high-resolution georeferenced measurements**, providing a comprehensive observational base for further specialist analysis.

This wealth of data can be used by **climate scientists, urban planners, researchers and other domain experts** to extract information directly applicable to urban planning and climate adaptation.

The process can be summarized as: **measurement → data → information → indicator → decision support**.

The high spatial and temporal density of observations makes it possible to **generate urban climate products** that cannot be obtained from the fixed-station network alone.

7.1 High-resolution mapping of the Urban Heat Island

Aggregating observations collected over weeks, months and seasons will make it possible to identify:

- recurring thermal hot spots;
- cool spots;
- thermal gradients between neighbourhoods;
- differences between the urban centre, peripheral areas and coastal zones;
- thermal behaviour of different types of urban fabric;
- daily and seasonal evolution of the Urban Heat Island.

The result may consist of **street-level climate maps** whose spatial coverage is determined by the extent of the routes travelled by the MeteoBus fleet.

8. Support for climate adaptation strategies

The MeteoBus network can become a **permanent urban climate-intelligence infrastructure**.

8.1 Urban planning

The data can provide **quantitative evidence** for:

- identifying priority areas for intervention;
- planning new green infrastructure;
- defining green and climate corridors;
- selecting areas where tree cover and shading should be increased;
- assessing depaving strategies;
- designing climate-resilient public spaces.

8.2 Assessment of intervention effectiveness

Measurements can be used in a **before/after approach**, comparing microclimatic conditions before and after interventions such as:

- new tree planting;
- parks;
- green routes;
- high-reflectance pavements;
- shading systems;
- green and blue infrastructure.

This makes it possible to move from simply implementing an intervention to **quantitatively measuring the climate benefit** it produces.

8.3 Heat-risk mapping

By integrating MeteoTracker observations with **territorial and demographic information**, maps can be developed for:

- heat exposure;
- thermal stress;
- urban vulnerability;
- climate risk.

Particular attention can be given to areas frequented by more vulnerable groups such as older people, children and people with medical conditions.

8.4 Real-time alerts and climate services

The high update frequency of the mobile network can support systems for:

- identifying particularly critical thermal conditions;
- monitoring heat waves;
- identifying local hot spots;
- supporting location-specific alerts;
- public information.

In the future, **composite thermal comfort and heat stress indicators** could be developed for easy use by non-specialist users.

9. Support for modelling and Artificial Intelligence

The dataset produced by the MeteoBus network has particularly valuable characteristics for **urban modelling and AI/Machine Learning applications**.

The large volume of georeferenced observations can be correlated with:

- urban morphology;
- land use;
- vegetation cover;
- building density;
- building height;
- solar radiation;
- satellite observations of surface temperature;
- synoptic meteorological data;
- information from fixed sensors.

This will enable the development of models capable of estimating microclimatic conditions even in areas and time intervals that are not directly sampled.

The MeteoTracker network could therefore provide **the ground-truth high-resolution** required for the calibration and validation of urban climate models, Digital Twins and Artificial Intelligence algorithms.

10. Environmental quality monitoring

If the network configuration also includes MeteoTracker sensors dedicated to **air quality**, the same infrastructure can be used to simultaneously analyse:

- meteorological conditions;
- airborne particulate matter;
- spatial distribution of pollutants;
- relationship between traffic, urban morphology and air quality.

The ability to **directly correlate meteorological and environmental data** acquired at the same location and at the same time provides additional value to the system.

11. Expected outputs

The deployment can produce a **structured set of outputs**, including:

- georeferenced urban microclimate dataset;
- high-resolution Urban Heat Island maps;
- identification of hot spots and cool spots;
- Virtual Fixed Station time series;
- systematic comparison with the fixed-station network;
- climate indicators by neighbourhood and observation corridor;
- heat-exposure and heat-risk maps;
- analysis of the effectiveness of green infrastructure;
- indicators for climate-resilient urban design;
- data for alert systems;
- calibration datasets for forecasting models and AI;
- APIs for integration with the Smart City platform;
- dashboards and information products for public decision-makers.

12. Strategic value for the metropolitan territorial system

The MeteoBus platform could provide territorial governance with a **permanent urban climate-intelligence infrastructure** by opportunistically leveraging an infrastructure that is already in place and continuously operating: **the public transport network**.

By equipping vehicles with fully automated MeteoTracker systems, the existing mobility of the fleet can be transformed into a **distributed, high-resolution urban microclimate observation network**, without requiring any changes to transport operations or any intervention by drivers.

The **key added value** lies in the ability to turn the routine operation of public transport into an **unprecedented source of extensive, continuous and spatially dense environmental information**, transforming data collected across the urban area into **actionable climate intelligence**. This information can directly support urban planning, assessment of adaptation measures, climate-risk management and emergency response.

The approach therefore creates a **multiplication effect**, extracting a new climate-information service from an infrastructure originally designed for an entirely different purpose, with no interference with its primary function. Based on a mature and extensively field-tested climate-intelligence infrastructure, the **MeteoTracker MeteoBus model** can be **readily scaled across metropolitan areas**, turning existing public transport networks into permanent, high-resolution urban **climate observation systems**.

Further information and contacts

For further information on the MeteoTracker platform, its applications in urban environmental monitoring and integration with Smart City infrastructures, please contact the MeteoTracker team.

- Email: info@meteotracker.com
- Website: www.meteotracker.com
- LinkedIn: https://www.linkedin.com/showcase/meteotracker/